BBC

EXPLORE THE NIGHT SKY WITH BINOCULARS

Tour 10 top targets **PLUS** 3 pairs of 7x50s on test

#184 SEPTEMBER 2020

Sky at Night

THE UK'S BEST SELLING ASTRONOMY MAGAZINE

THE LIFE AND DEATH OF STARS

From stellar nurseries to supernovae, discover the life cycle of stars in this month's night sky

NEW SEASON STAR-HOPPING

An easy trip around the constellations of autumn

UNLOCKING DARK ENERGY

Does new research explain what's pushing the Universe apart?

RED PLANET IN REVERSE

Observe Mars's curious orbital loop this month

STARS ON THE CEILING

Make your own indoor planetarium projector

A MONTH OF MEETINGS

See 5 great conjunctions of the Moon and planets

COMET NEOWISE

Your experiences of 2020's great comet

Welcome

Join us under the stars as we welcome back the longer nights

As we move into the new autumn season the days start to shorten noticeably and we amateur astronomers welcome the return of long dark nights. It's the ideal time to discover more in the night sky and this issue will help you on your way to doing just that, whether it's with the naked eye, a pair of binoculars or a telescope.

On **page 64**, Scott Levine takes us on an easy naked-eye tour of the main constellations in September's night sky – an ideal way to get your bearings among the glittering stars of the celestial sphere. Then on **page 55**, Steve Tonkin singles out 10 great targets to observe with binoculars – sparkling clusters and star clouds that look their best in the wide-field views that binoculars provide. Starting easy, there are several objects later in the tour that will test your observing skills as you get your eye in.

Mars is improving as a telescope target, its increases in size and brightness throughout September whetting the appetite for an exciting opposition next month. In preparation, on **page 60** Pete Lawrence examines what is now telescopically visible on the Red Planet and looks at the retrograde loop which Mars appears to perform in its orbit from this month on. The planet also has a lovely close meeting with the Moon this month. It's one of several bodies to do so, which you can discover in the Sky Guide from **page 39**.

Lastly, on **page 26** Stuart Atkinson takes us on a night-sky tour themed around the life cycle of stars, stopping off at objects which show all the stages, from birth in nebular nurseries to the final chapter for some in dramatic supernovae.

Chris Bramley, Editor

PS Our next issue goes on sale on Thursday 17 September.

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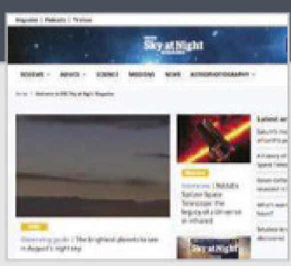
Sky at Night – lots of ways to enjoy the night sky...

Television
Find out what *The Sky at Night* team have been exploring in recent and past episodes on page 16



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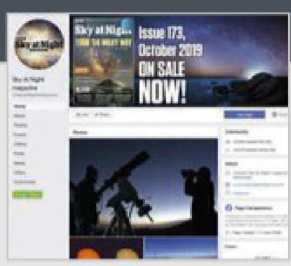

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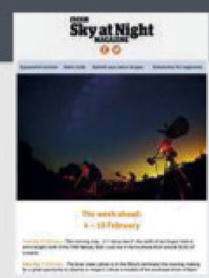

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The best targets to observe each week, delivered to your inbox. Visit **bit.ly/skynewsletter**

Find out more at: www.skyatnightmagazine.com

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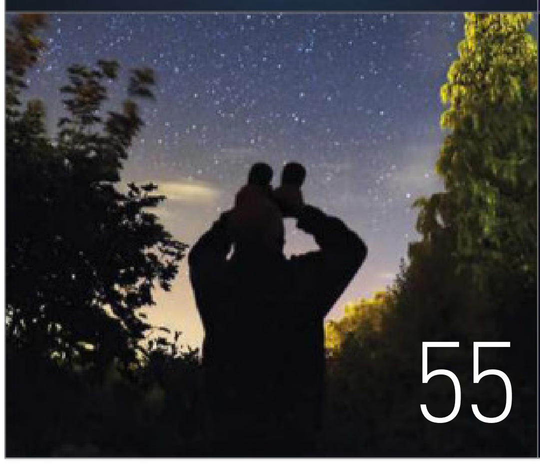
16-PAGE STARGAZING GUIDE

The Sky Guide

COVER MAIN IMAGE: SOUBRETTE/ISTOCK/GETTY IMAGES. THIS PAGE: NASA/ESA/M. ROBBERTO (SPACE TELESCOPE SCIENCE INSTITUTE/ESA) AND THE HUBBLE SPACE TELESCOPE ORION TREASURY PROJECT TEAM, PETE LAWRENCE X 2, JON HICKS, COKADA/ISTOCK/GETTY IMAGE, @THESHED_PHOTOSTUDIO, BBC

New to astronomy?

To get started, check out our guides and glossary at **www.skyatnightmagazine.com/astronomy-for-beginners**



This month's contributors

Stuart Atkinson

Astronomer & writer

"I wrote this feature as children often ask me how we know what will happen to our Sun – they are amazed to learn it's a star, then horrified to learn it's going to die one day!" **Stuart explores the life cycle of stars,** **page 26**

Shaoni Bhattacharya

Science journalist

"I found it fascinating to learn just how stars go 'gamma-ray burst'; this interview left me reeling at the thought that these explosions can blow the stuffing out of galaxies". **Shaoni meets an extragalactic star modeller,** **page 90**

Scott Levine

Astronomy blogger

"I liked writing this month's sky tour because I enjoy seeing the sky change with the seasons; it's a chance to visit familiar stars and constellations." **Scott points out the highlights of autumn's night sky,** **page 64**

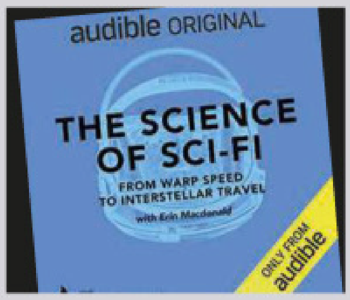
Extra content ONLINE

Visit **www.skyatnightmagazine.com/bonus-content/R4PLDQF/** to access this month's selection of exclusive Bonus Content

SEPTEMBER HIGHLIGHTS

Interview: a new mission to Triton

Planetary scientist Louise Prockter reveals her proposed mission to send a spacecraft to Neptune's largest moon.



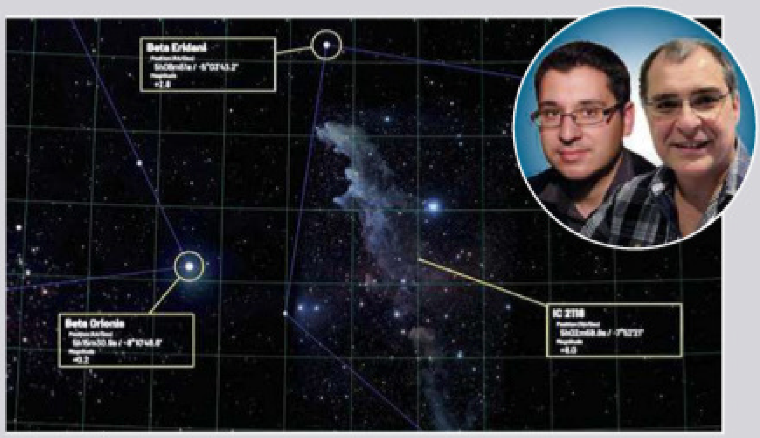
Watch July's episode of *The Sky at Night*

The team explore the life and death of stars, including the latest news on Betelgeuse and how to do safe solar astronomy.

Audiobook preview: The Science of Sci-Fi

Are artificial gravity and time travel possible? Listen to two lectures from a new audio book on the science of sci-fi.

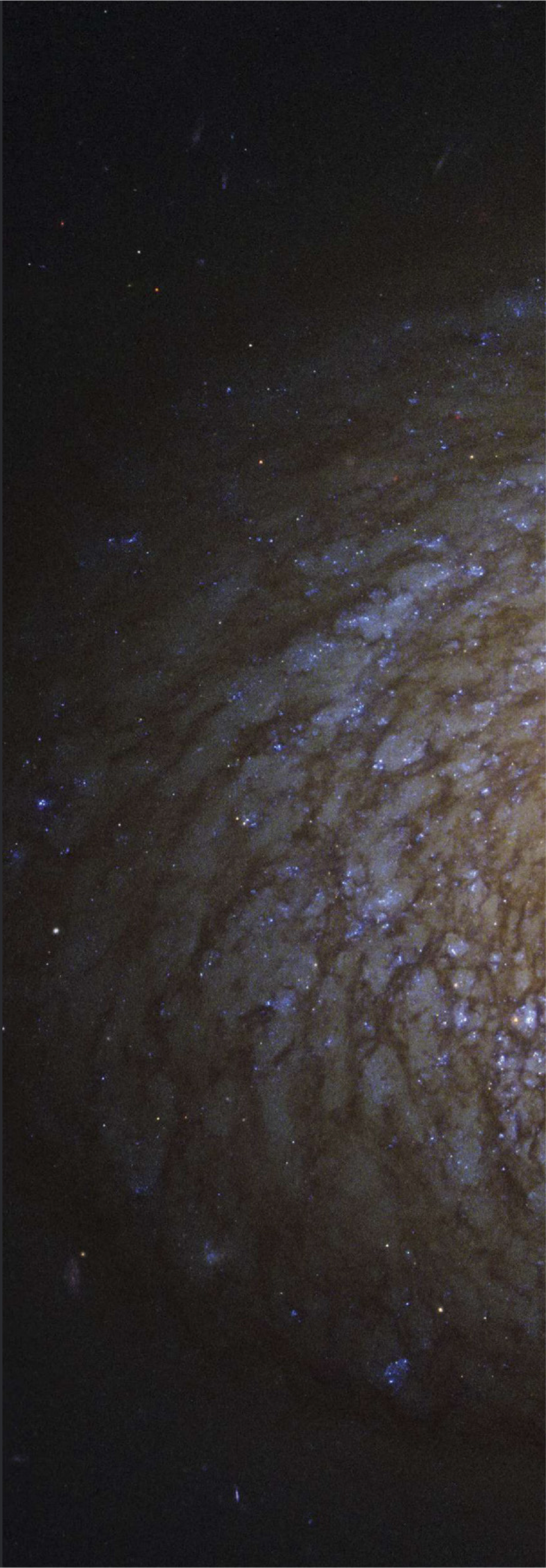
The Virtual Planetarium



Pete Lawrence and Paul Abel guide us through the best sights to see in the night sky this month.

A SPIRAL WITH A SOFT CENTRE

Blue stars glitter on the feathery arms of a flocculent galaxy

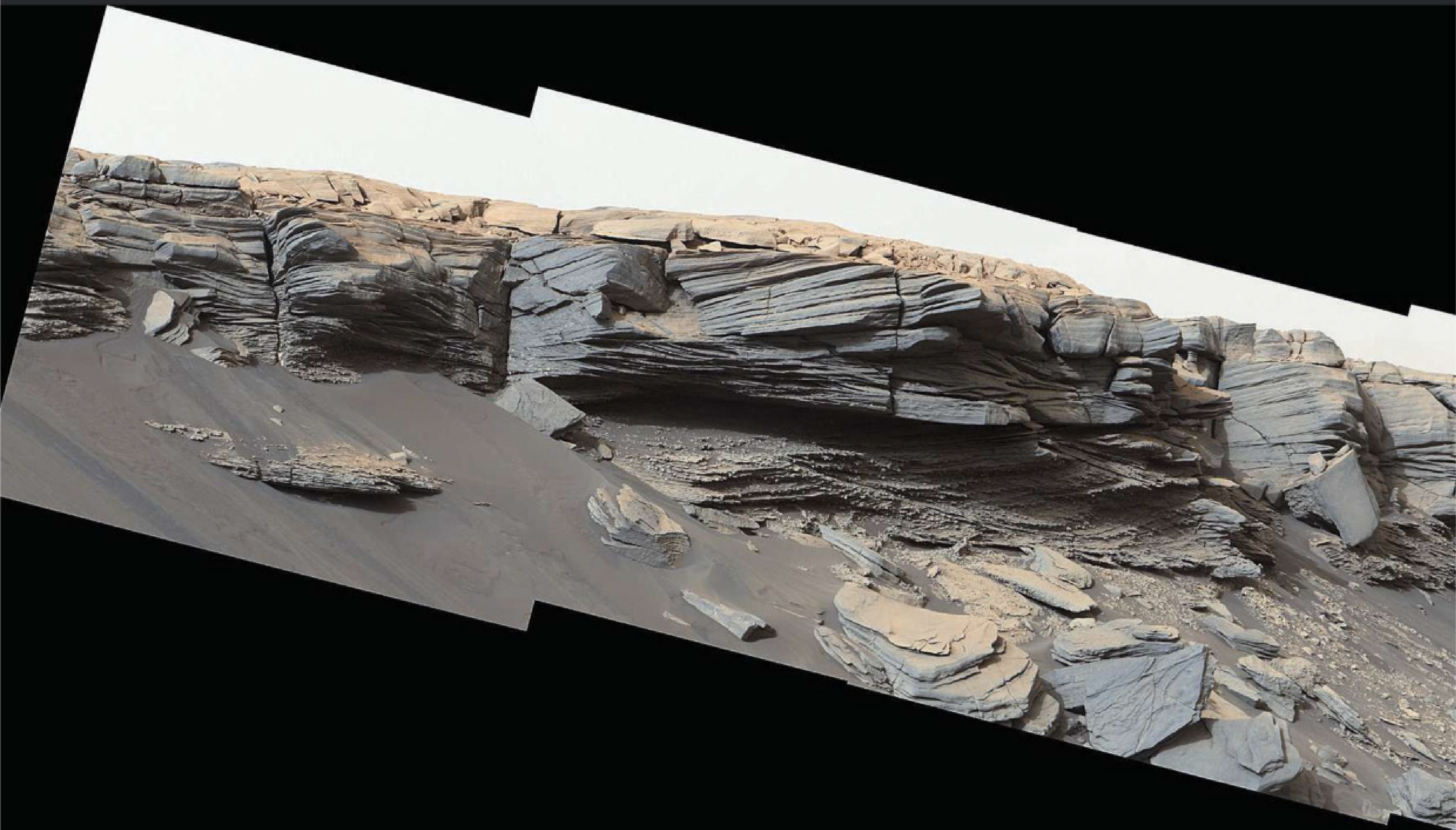


ESA/HUBBLE & NASA/J. LEE AND THE PHANGS-HST TEAM; ACKNOWLEDGMENT: JUDY SCHMIDT (GECKZILLA)

HUBBLE SPACE TELESCOPE, 2 JULY 2020

The fluffy spiral arms and the curiously large empty region at its heart are the signs of a sleepy galaxy in repose. NGC 2775, located 67 million lightyears away in the constellation of Cancer, has its furious period of star production long behind it, leaving a vacant centre where its concentrated reserves of gas were converted to stars long ago. The woolly, ill-defined spiral arms, across which are scattered millions of blue stars, are what give 'flocculent' type galaxies their name; in contrast to the distinct, continuous arms of grand design spirals.

MORE **ONLINE**
A gallery of these and more stunning space images



△ On the rocks

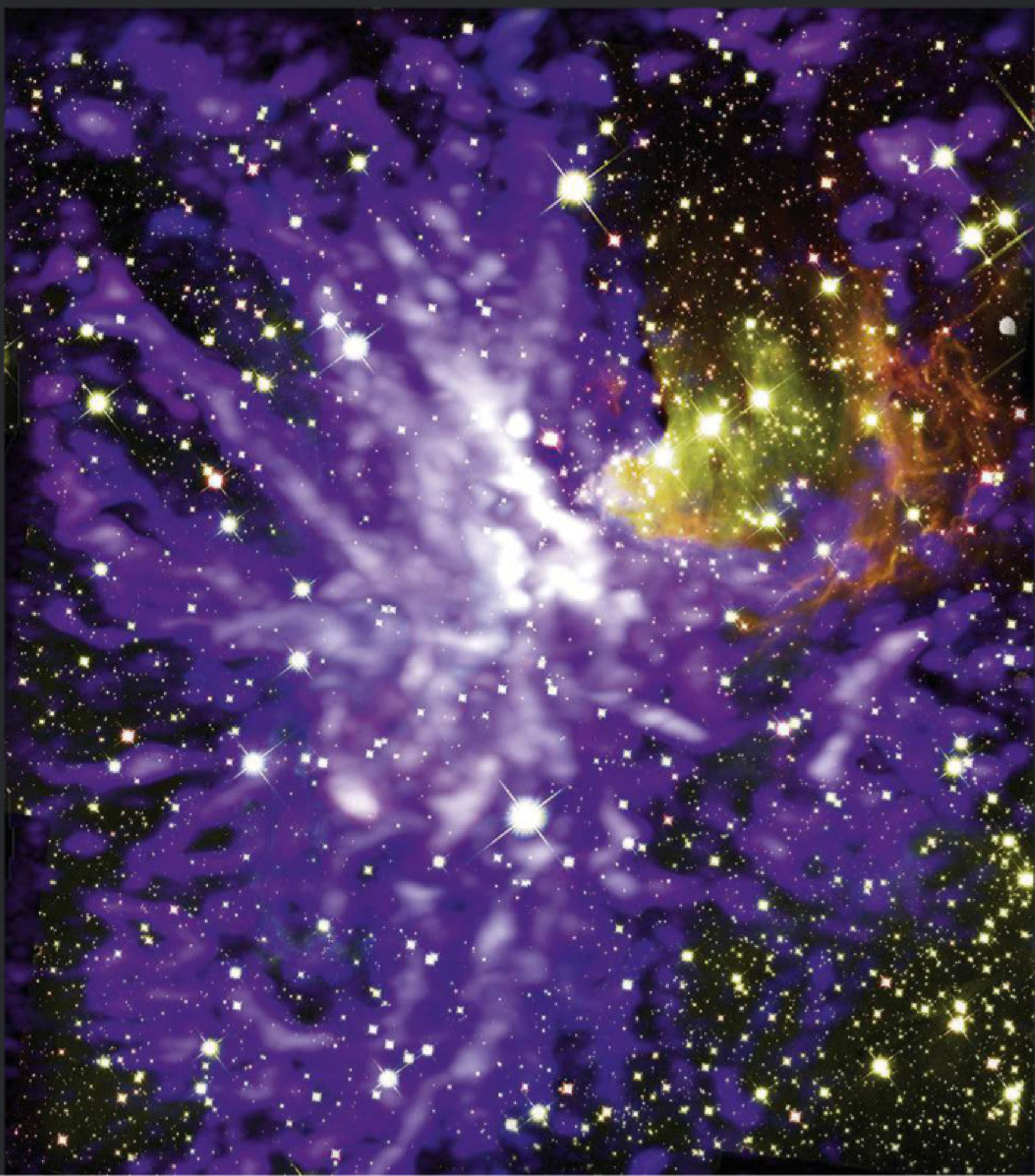
CURIOSITY MARS ROVER, 6 JULY 2020

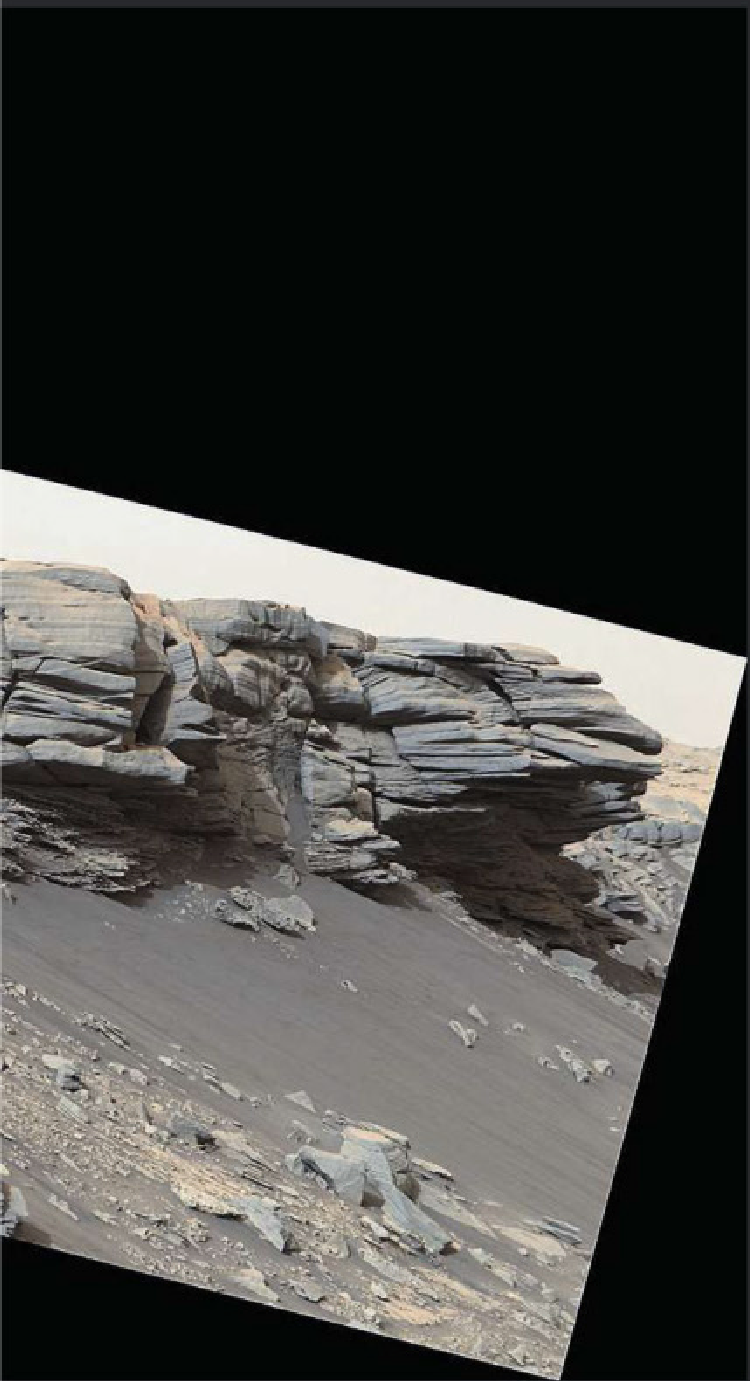
Curiosity captured this image with its Mastcam on a summer road trip that involved driving up its steepest incline yet. The rover has been scaling the 5km-high Mount Sharp, on the floor of Gale Crater, since 2014 and took this photo of the Greenheugh Pediment on its 2,729th Martian day, or sol. Now in a sulfate-bearing area, Curiosity is examining the mountain's sedimentary layers for clues about Mars's former climate and prospects for life.

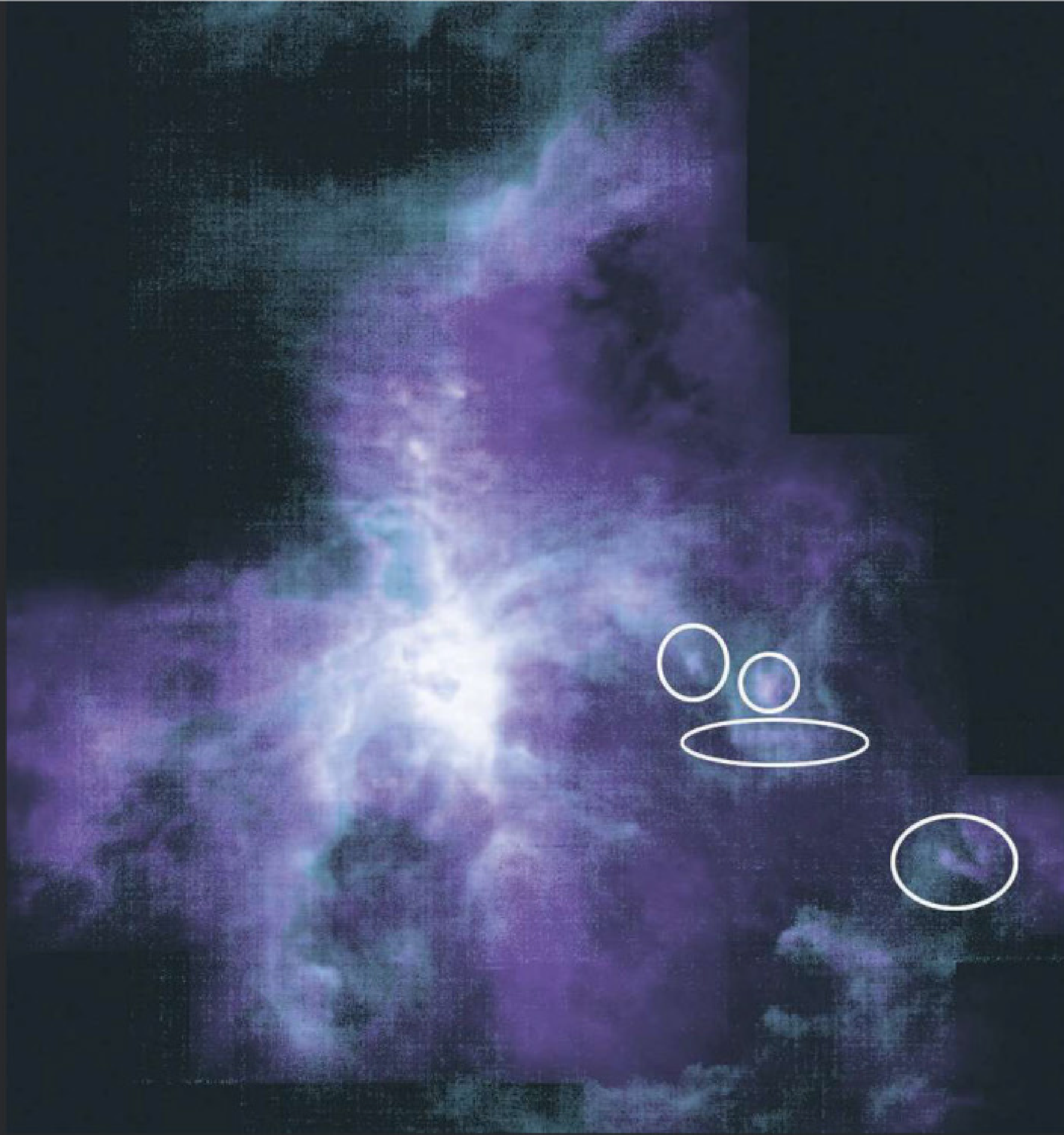
Cosmic fireworks ▷

ATACAMA LARGE MILLIMETER/ SUBMILLIMETER ARRAY, HUBBLE, 2 JULY 2020

This composite shot reveals star formation in the cluster G286.21+0.17, about 8,000 lightyears away in the Carina region. A mosaic of 750 ALMA radio images and nine Hubble infrared images, it shows molecular gas clouds (purple) that will coalesce to create stars, and wisps of hot dust (yellow and red) – the remnants left when stellar winds from massive stars blast away the molecular clouds.







△ Cloudy with a chance of stars

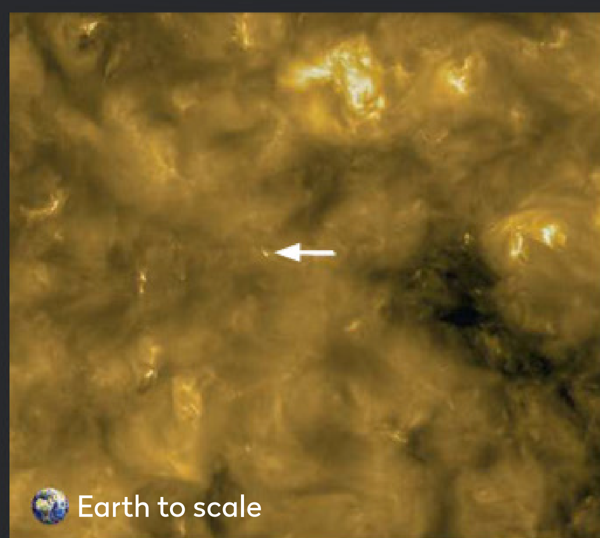
SOFIA, IRAM, 1 JULY 2020

Combining data from NASA's Boeing-borne SOFIA telescope and the 30m radioscope at the Institute for Radio Astronomy in the Millimeter Range (IRAM), this image seems to capture stars being born in the Orion Nebula, the closest active star-forming region to Earth. It shows densely packed dust clouds (circled) which researchers believe are emergent low-mass stars.

◁▽ Campfires on the Sun

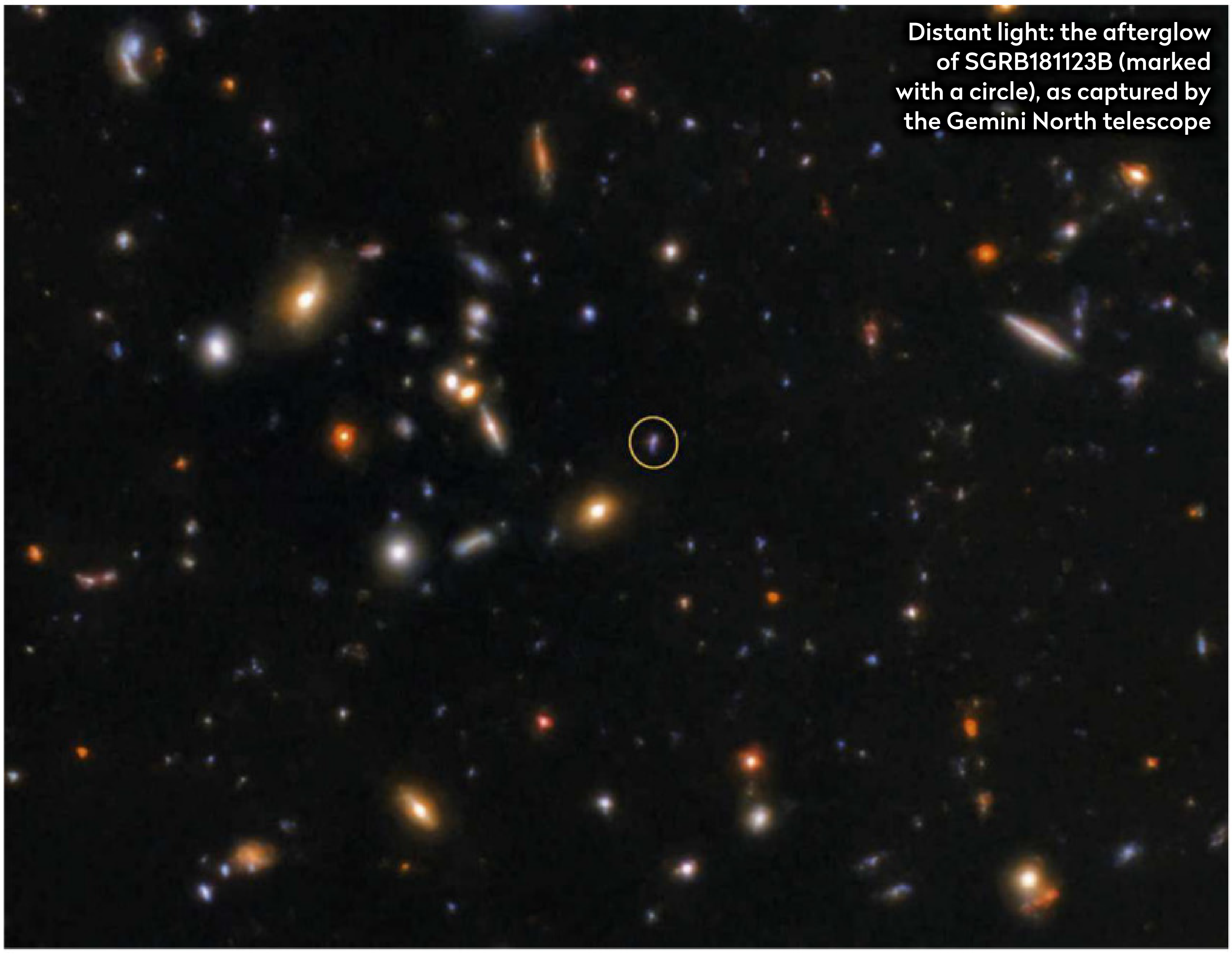
ESA/NASA SOLAR ORBITER, 16 JULY 2020

Why is the Sun's surface 6,000°C while its corona reaches a million degrees, despite being further from the nuclear core? This mystery is one focus of the ESA/NASA Solar Orbiter mission, which in July snapped the closest pictures of our star to date, passing 77 million km from its surface. They reveal masses of erupting flares, dubbed 'campfires' – each the size of a small European country – that may help explain the corona's extreme heat. The arrow in the close-up image below points to one example of these campfires on the solar surface.



NASA/JPL-CALTECH/MSSS, ALMA (ESO/NAOJ/NRAO) Y. CHENG ET AL/NRAO/AUI/NSF/S. DAGNELLO/NASA/ESA HUBBLE, NASA/SOFIA/IRAM, SOLAR ORBITER/EUI TEAM/PHI TEAM/ METIS TEAM/SOLOHI TEA /ESA & NASA

BULLETIN



Distant light: the afterglow of SGRB181123B (marked with a circle), as captured by the Gemini North telescope

Gamma-ray burst afterglow seen across the Universe

It's the most distant optical indication of a short burst ever detected

The afterglow of one of the most intense explosions in the Universe – a short gamma-ray burst (SGRB) – has been spotted further away than ever before. A recent article announced the explosion was 10 billion lightyears away, meaning the blast occurred when the Universe was just 3.8 billion years old.

SGRBs are intense bursts of gamma radiation which flash across the Universe, believed to be produced by two neutron stars merging. They earn their 'short' moniker, however, as the optical component lasts only a few hours, leaving astronomers little time to catch this part of the outbursts before they fade away from view.

When astronomers received word on 22 November 2018 that an SGRB had been detected by NASA's Neil Gehrels Swift Observatory, they were able to remotely access the Gemini North telescope on Mauna Kea in Hawaii. Using this, they pinned down exactly which galaxy the burst came from.

"With SGRBs, you won't detect anything if you get to the sky too late," says Wen-fai Fong from Northwestern University, who took part in the study. "But every once in a while, if you react quickly enough, you will land on a beautiful detection like this."

With the host galaxy known, the team were able to use the Gemini South telescope in Chile to pin down its distance at 10 billion lightyears away, meaning the blast dates from the Universe's 'teenage' years.

"It's long been unknown how long neutron stars – in particular those that produce SGRBs – take to merge. Finding an SGRB at this point in the Universe's history suggests that, at a time when the Universe was forming lots of stars, the neutron star pair may have merged fairly rapidly," says Fong.

www.gemini.edu

Comment

by Chris Lintott

Short gamma-ray bursts (SGRBs) are fascinating objects, explosions bright enough to be seen on the other side of the visible Universe. Swift's studies have helped to pin down the causes of these enigmatic events, and have set people wondering if they could help us solve the mystery of how fast the Universe is expanding. Our modern techniques – one involving the cosmic microwave background, and another supernovae – produce differing results. If SRGBs can be shown to be 'standard candles' then they can be used to measure distance, and hence the expansion rate. Objects capable of doing that, which are bright enough to be visible across more than 10 billion years of cosmic time, would be valuable – and SGRBs may be the start.

Chris Lintott co-presents *The Sky at Night*

INTERNATIONAL GEMINI OBSERVATORY/NOIRLAB/NSF/AURA/K. PATERSON & W. FONG (NORTHWESTERN UNIVERSITY). IMAGE PROCESSING: TRAVIS RECTOR (UNIVERSITY OF ALASKA ANCHORAGE), MAHDI ZAMANI & DAVIDE DE MARTIN, WILL GATER, NASA/JPL-CALTECH

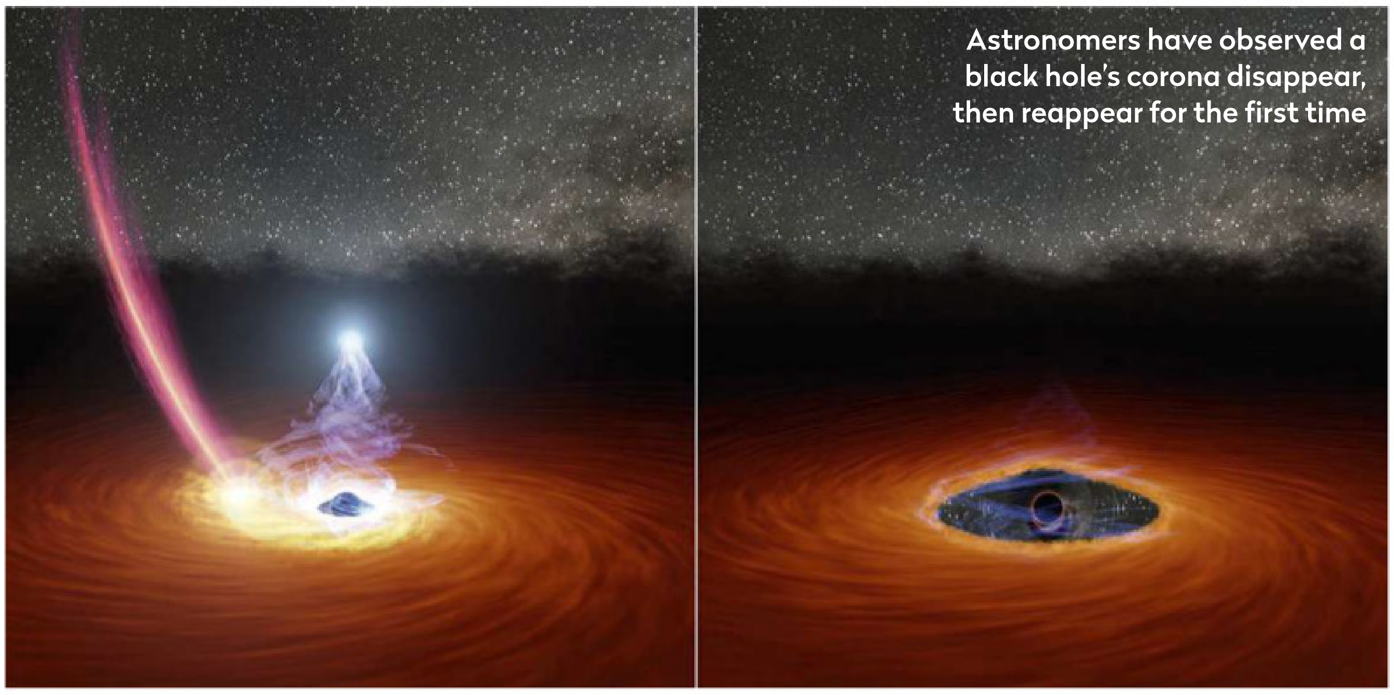
Summer visitor: Comet NEOWISE has been one of this year's observing highlights

Comet NEOWISE puts on a show

The comet could be seen throughout the Northern Hemisphere

Throughout July, astronomers were delighted by Comet C/2020 F3 (NEOWISE) as it streamed across the sky. The comet was discovered on 27 March by NASA's Near-Earth Object Wide-field Infrared Survey Explorer (NEOWISE) telescope. It passed through perihelion on 3 July and made its closest approach to Earth on 23 July. In early July, astronomers began to report that the comet was visible to the naked eye – an unexpected joy for stargazers after two promising comets earlier this year, SWAN and ATLAS, turned out to be rather lacklustre. As the news hit the headlines around the world, astronomers new and old rushed out to see the sight for themselves, with many capturing it on camera. Go to **bit.ly/cneowise** to see a gallery of readers' best images on our website.
www.nasa.gov/neowise

Corona reappears – around a black hole



Astronomers have observed a black hole's corona disappear, then reappear for the first time

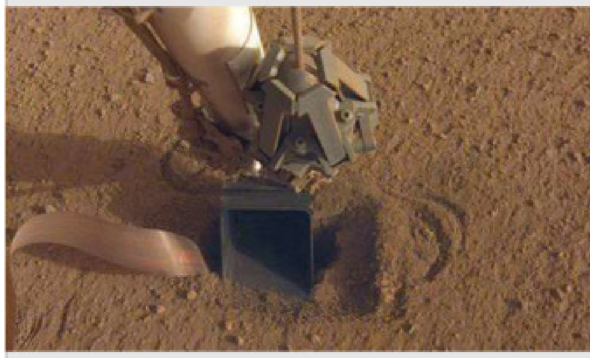
ILLUSTRATION

Astronomers have witnessed the demise and rapid rebirth of a black hole's corona, a new study has revealed.

In 2018, astronomers noticed that the corona – the billion-degree ring of particles surrounding the event horizon – of an otherwise unremarkable black hole was rapidly dimming. "We expect luminosity changes this big should vary over many thousands to millions of years," says Erin Kara from MIT, who took part in the study. "But in this object we saw it change by a factor of 10,000 over a year, and it even changed by a factor of 100 in eight hours, which is just totally unheard of."

It's thought a star straying too close to the black hole caused the dimming; it ricocheted around, dragging the corona particles into the black hole. Then, a few months later, a new corona began forming. "This seems to be the first time we've seen a corona first of all disappear, but then rebuild itself, and we're watching in real time," says Kara.
www.mit.edu

NEWS IN BRIEF



InSight's heat probe woes

In June, after 18 months, NASA's Martian InSight lander managed to bury the head of its heat probe, HP3. HP3 was meant to hammer itself 5m into the ground last year, but couldn't gain purchase on the loose soil. Using the lander's robot arm, the InSight team have pushed the probe into the ground, but are now struggling to dig any deeper.

Heavyweight singularity

A black hole which devours a solar mass of material per day has had its mass measured. J2157 weighs 34 billion solar masses – one of the heaviest black holes known. "If the Milky Way's black hole wanted to grow that fat, it would have to swallow two-thirds of all our Galaxy's stars," says Christopher Onken from the Australian National University, who led the study.

Venus volcanoes active

Venus might not be as dead as once thought, as a new study has identified 37 volcanic structures which are still active. "This study changes the view of Venus from a mostly inactive planet to one whose interior is still churning and can feed active volcanoes," says the University of Maryland's Laurent Montési.

Main image: the UAE's Hope spacecraft launches into space on 19 July. Above left: Hope will monitor the Red Planet's weather and climate. Below: NASA's Perseverance will collect samples from the surface, ready for return to Earth

Three nations lift off for the Red Planet

Mars is set to get busier after a trio of missions use this summer's launch window

Three missions launched for Mars in July, taking advantage of the planet's launch window this summer – when Earth was close enough to the Red Planet to dramatically reduce the time taken to reach Mars. With the next window 26 months away, three space agencies surmounted technical problems and pandemics to reach the launch pad.

First to launch was the Hope probe from the United Arab Emirates – the country's first planetary space mission – which launched from the Tanegashima Space Centre in Japan on 19 July. Once at Mars, Hope will act as a weather and climate monitoring station.

"One of the requirements very early on was to send a mission that does more than capture an image declaring that the UAE reached Mars," said Sarah al-Amiri, UAE's minister of state for advanced sciences and the deputy project manager of Hope. "We are the very first weather satellite for Mars."

Then on 23 July, the Chinese National Space Administration (CNSA) launched its first Mars mission, Tianwen-1 which builds on the successes of the Chang'e lunar landers.

The orbiter half of Tianwen-1 will spend its first few months at Mars scouting out a landing site for its other half, a rover. This vehicle will then study the rocks on the surface, while also using radar to examine those beneath it. The orbiter, meanwhile, will monitor the planet from above.

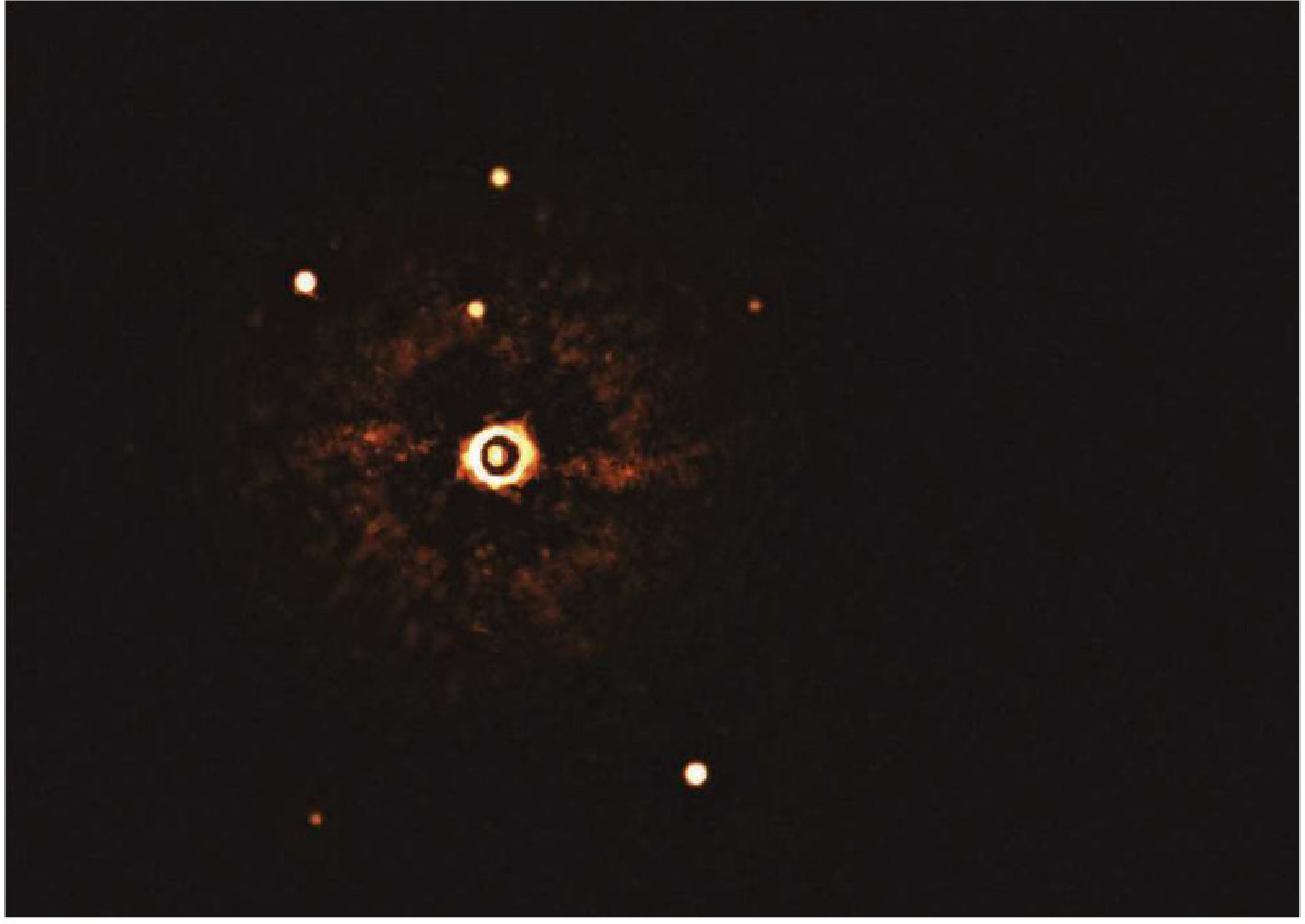
"Tianwen-1 is a landmark project in the process of building China's space prowess and a milestone project for China's aerospace to go further and deeper into space," says Wu Yansheng, the mission's deputy project commander.

The launch window for the final mission, NASA's Perseverance rover, opened on 30 July, after this issue had gone to press. The rover is NASA's latest step towards bringing back samples from the Martian surface. It will create caches of soil and rock that a future mission will collect and return to Earth.

A fourth mission, ESA's Rosalind Franklin rover, won't be joining the trio as problems with its landing system meant its launch date had to be pushed back to 2022. The three missions which did make it to the launch pad, however, are due to arrive at Mars in February 2021, when their real work begins.

www.emiratesmarsmission.ae; www.cnsa.gov.cn; www.nasa.gov

DISCOVERMHI (MITSUBISHI HEAVY INDUSTRIES LTD, (MOHAMMED BIN RASHID SPACE CENTRE), NASA/JPL-CALTECH, ESO/BOHN ET AL, NORR CONSULTING, NASA'S GODDARD SPACE FLIGHT CENTER CONCEPTUAL IMAGE LAB/MICHAEL LENTZ



▲ Perfect catch: the image of the star, TYC 8998-760-1, accompanied by two giant exoplanets

Distant gas giants caught on camera

Multiple planets directly observed around a Sun-like star

Marking an important step towards studying potentially habitable planets, astronomers have taken the first ever direct image of a multiple planet system around a Sun-like star, using the ESO's Very Large Telescope in Chile.

By taking a series of images with a coronograph, which blocks out the central star's light, astronomers picked out the planets as they moved relative to the static background stars. "Even though astronomers have indirectly detected thousands of planets in our Galaxy, only a tiny fraction of these exoplanets have been imaged directly," says Matthew Kenworthy from Leiden University, who helped conduct the study.

Though the planets are unlikely to host life – they're gas giants many times further out from their star than Pluto is from our Sun – such direct imaging will be an important tool for assessing the habitability of more promising worlds. **www.eso.org**

Ups and downs for UK space industry

In the pipeline: the proposed spaceport layout in the Scottish Highlands

The UK space industry has had mixed luck over the last few months. Things began well on 29 June, when the Highland Council approved the building of a spaceport in Sutherland. The plans will now go through an environmental survey and a Scottish government review.

Then on 1 July, UK companies lost out on contracts to build satellites for ESA's Copernicus Earth-monitoring system, as these are only open to EU member states. The UK is currently negotiating how it will take part in the future.

And on 3 July, the UK Government announced it was joining with Indian company Bharti Global to acquire British satellite company OneWeb. The new investment will enable OneWeb's goal of creating a constellation of over 600 communication satellites, and also explore its potential use as a navigation system.

"The deal presents the opportunity to further develop our strong advanced manufacturing base right here in the UK," said Business Secratary Alok Sharma. **bit.ly/2OXFOP5**

NEWS IN BRIEF

Balloon telescope

NASA has plans to build a new scope, ASTHROS, to examine the Universe at submillimetre wavelengths. As such light is blocked by Earth's atmosphere, the 2.5m-wide scope will be floated 40km in the air by a weather balloon. "Balloon missions like ASTHROS are riskier than space missions, but yield high-rewards at modest cost," says project manager Jose Siles.

Super-Earth, dwarf star

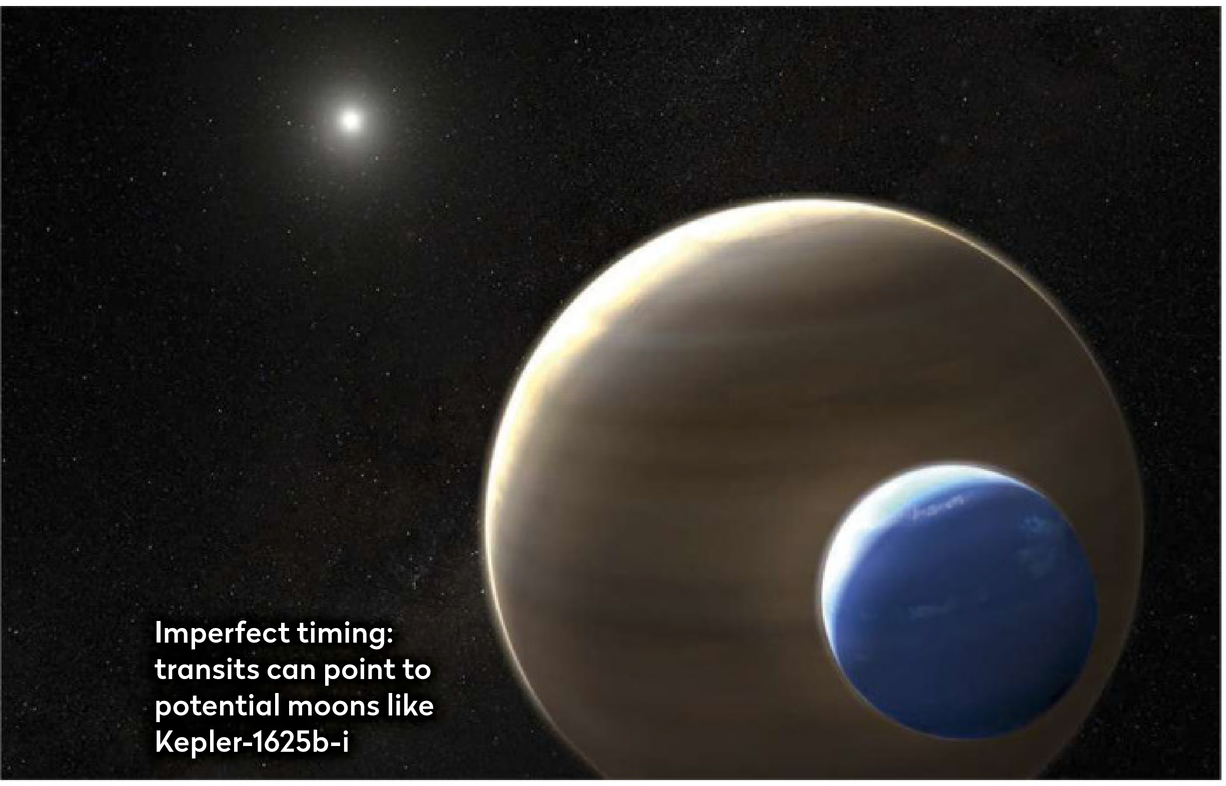
A pair of super-Earths have been discovered around a red dwarf star, Gliese 887, just 11 lightyears away. One of the planets is in the region where liquid water could persist on its surface. Astronomers will now attempt to examine the planet's atmosphere – a task which is much easier for a nearby red dwarf than a more distant or brighter star.

National Astronomy Week 2020

Mark 14–22 November in your diary: it is National Astronomy Week 2020. The aim of this year's event is to get as many people as possible seeing Mars through a scope, and has been timed for when the Red Planet is highest in the evening sky. Visit **astronomyweek.org.uk**.

Our experts examine the hottest new research

CUTTING EDGE



Imperfect timing: transits can point to potential moons like Kepler-1625b-i

Detecting distant moons

Unseen moons may be revealed by their gravitational tug on exoplanets

Astronomy entered the golden age of detecting alien worlds in the early 1990s. In the three decades since, we've found almost 4,300. Now, as technology advances, we are able to delve deeper into these systems, including the ability to detect unseen moons orbiting these worlds. In October 2018, using observations from the Hubble Space Telescope, astronomers announced gas giant planet Kepler-1625b could have a smaller companion orbiting it, although this detection is as yet unconfirmed and remains controversial.

Discovering dark planets orbiting dazzlingly bright stars across lightyears of space is itself impressive enough; but detecting the presence of even tinier, unseen moons around these remote worlds is truly formidable. The trick is to scrutinise the data gathered from transiting exoplanets – those that are detectable by the dip in starlight they cause as they pass in front of their star, from our point of view. If a transiting exoplanet itself has an orbiting companion, it will rotate around the mutual centre of mass of the planet–moon system. In effect, if the invisible moon happens to be ahead of the exoplanet during a transit, its gravitational tug will pull the planet forward slightly, and the transit will begin a little earlier than expected, or conversely hold it back. So precise measurements of the transit timing variations, or TTVs, of an exoplanet can reveal the presence of an unseen exomoon.

NASA/ESA AND L. HUSTAK (STSCI), ALMA (ESO/NAOJ/NRAO) J. HUANG AND S. ANDREWS/NRAO/AUI/NSF/S. DAGNELLO

"If the invisible moon happens to be ahead of the exoplanet during a transit, its gravitational tug will pull the planet forward slightly"

Prof Lewis Dartnell is an astrobiologist at the University of Westminster

For example, in the Earth–Moon system, the orbiting mass of the Moon creates TTVs in our planet's passage across the solar disc every year (from the point of view of an appropriately positioned alien astronomer) of up to 2.5 minutes. In its hunt for exoplanets the Kepler space telescope measured the brightness of stars every minute and so could, in principle, have indirectly detected our own Moon with this method, even though the direct transit signature from the Moon is only 7 per cent that of Earth and well below the threshold of what Kepler was sensitive to.

Six suspected satellites

In their hunt for potential exomoons, Chris Fox and Paul Wiegert, both at the University of Western Ontario, Canada, have been trawling through the huge dataset of transiting exoplanets discovered by the Kepler space telescope. They picked out the eight most promising systems that were known to exhibit TTVs and studied the data for each to test whether an exomoon companion was the best explanation for these orbital variations, or some alternative possibility such as the presence of an unknown, non-transiting planet in the system. Interestingly, this was how French astronomer Urbain Le Verrier was able to mathematically infer the existence and position of Neptune in 1846: the carefully measured irregularities in Uranus's orbital position betrayed the existence of a previously unrecognised new planet further out in the Solar System.

Using sophisticated statistical analysis, Fox and Wiegert found that the orbital variations of six of these transiting planets could indeed be accounted for by the gravitational tugs of an orbiting exomoon and that, importantly, such a moon would itself be stable and small enough to have escaped direct detection already. The TTVs could also be explained by a non-transiting exoplanet, but excitingly astronomers now have a list of half a dozen candidate exomoons to follow up on with further observations and analysis to potentially confirm their existence.

Lewis Dartnell was reading... *Exomoon Candidates from Transit Timing Variations: Six Kepler Systems with TTVs Explainable by Photometrically Unseen Exomoons* by Chris Fox and Paul Wiegert. **Read it online at https://arxiv.org/abs/2006.12997**

A spiralling star

The gas around star RU Lup looks more like a galaxy than a planetary system

Prof Chris Lintott is an astrophysicist and co-presenter of *The Sky at Night*

We think we understand star and planet formation. Clumps of gas and dust collapse under their own gravity to create a central star. This is surrounded by a disc of leftover material from which planets eventually form. Simple?

Well, new observations are beginning to show just how oversimplified this textbook picture may be. Take the young star RU Lup, the subject of a paper from Harvard's Jane Huang and colleagues. We know from previous observations that a substantial disc surrounds it, but these images can't tell the whole story. Much of the disc is made up of cold gas, mostly molecular hydrogen, which can't be easily seen.

Instead, the team used the ALMA (Atacama Large Millimeter/submillimeter Array) to look for emissions from carbon monoxide, another common molecule, and the extent and complexity of what was seen took them by surprise. The carbon monoxide disc is large, stretching out to 120 astronomical units from the star (for comparison, that's four times further than Neptune is from the Sun). In this region, the gas disc is what astronomers call Keplerian – the gas moves in its orbit just as planets would, following Kepler's laws of motion. There's more material further out, reaching all the way to 260 astronomical units, but this doesn't rotate with the rest of the disc.

Vast clumpy arms

Outside this 'envelope', things get really odd. There is more gas and it is arranged into a series of clumpy spiral arms. The arms aren't well defined – the paper notes that several different patterns could easily be drawn – but they're there, and they seem to reach out to about 1,000 astronomical units. That's about 150 billion kilometres! There are also clumps of gas that lurk out here, apparently not connected to the arms.

"RU Lup seemed simple, a nice disc on its way to making a solar system. But tune in to carbon monoxide and all this complexity jumps out"

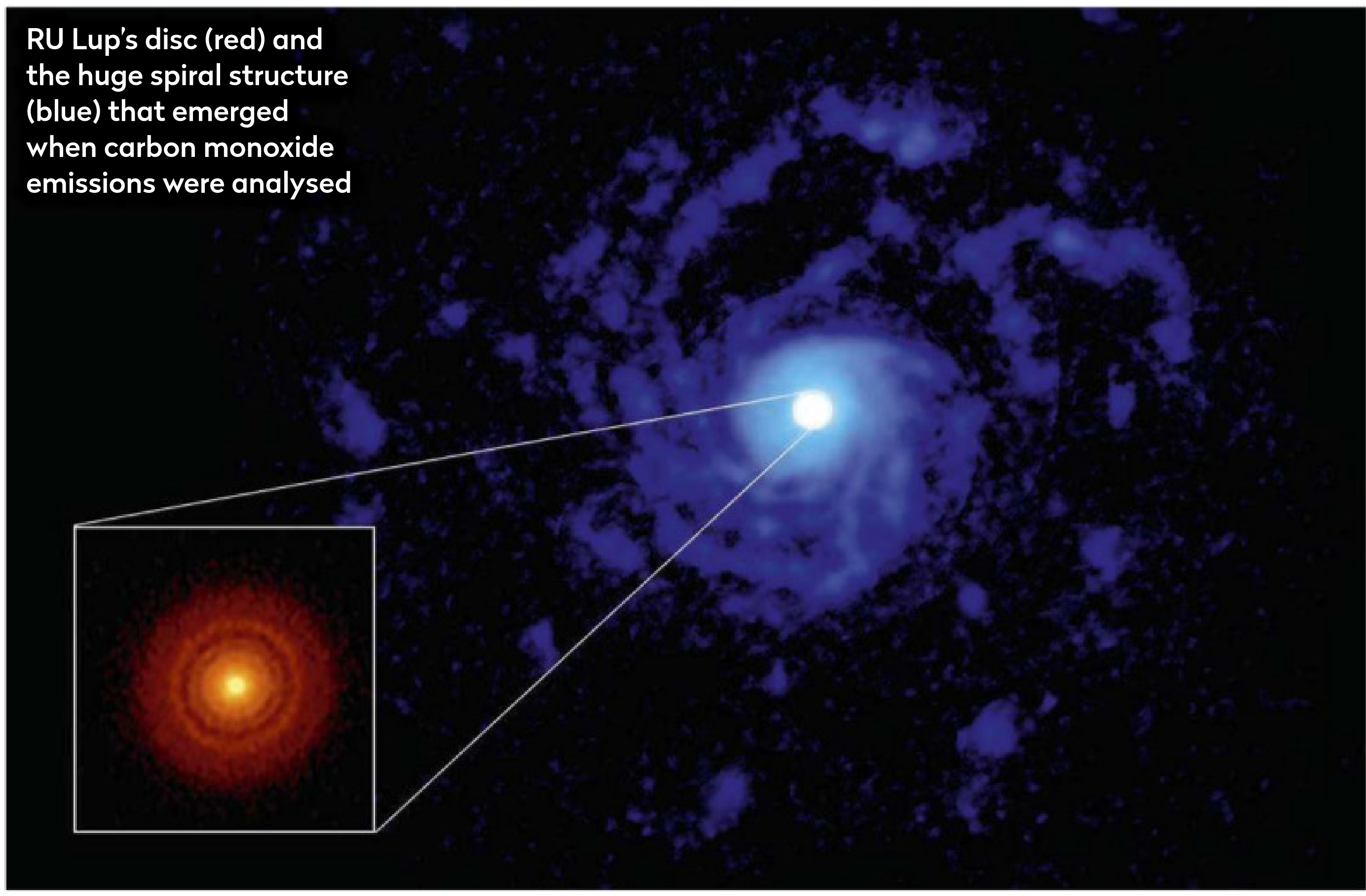
All of this structure makes RU Lup a textbook example of astronomical complexity. Viewed in those earlier images, it seemed simple: a nice disc on its way to making a solar system. Tune in to carbon monoxide, though, and all of this unsuspected complexity jumps out. So what's going on?

It's possible that some of the outer material is left over from the time that RU Lup was forming, but then why does it have the complex structure we see?

One set of options is that RU Lup did once have a nicely behaved disc, but it's been disrupted, either by an as yet unseen companion or by a recent close flyby from a neighbouring star. Unfortunately, such phenomena are believed to create spiral structures, but nothing so complex as what's observed here.

Perhaps the disc itself is unstable – a state which, on the vastly larger scale of galaxy-sized discs can produce spiral arms – but the outer material isn't rotating with the disc. Maybe winds from the young, unstable star play a role, or maybe it is some combination of all of these things, or none.

We don't know yet – but we have learnt the value of taking a close look at even apparently simple objects. Complex and confusing puzzles often lurk inside.



RU Lup's disc (red) and the huge spiral structure (blue) that emerged when carbon monoxide emissions were analysed

Chris Lintott was reading... *Large-scale CO Spiral Arms and Complex Kinematics associated with the T Tauri Star RU Lup* by Jane Huang et al. **Read it online at: https://arxiv.org/abs/2007.02974**

The Sky at Night TV show, past, present and future

INSIDE THE SKY AT NIGHT

▲ Clockwise from top left: Patrick Moore presents *The Sky at Night* in front of a studio map of Mars in 1969; and again with an image of the Red Planet in 1971; he is joined in the studio by Mars expert Dr Peter Cattermole; fast-forward to today and the Mars Yard in Stevenage is a backdrop for co-presenters Chris Lintott and Maggie Aderin-Pocock

As several nations begin journeys to the Red Planet, *The Sky at Night*'s producer **Simon Winchcombe** looks back through the BBC archives to see how our perception of Mars has changed in the last 50 years

Prompted by the upcoming missions to Mars, a chance conversation in the office led us to wonder how many past *Sky at Night* episodes had focused on the Red Planet. It turns out to be over 50, with the first broadcast in 1961. A further trawl through the BBC archive revealed more than 10 *Horizon* programmes on the same subject. Now, we thought, this was bound to be a treasure trove of images, ideas and discoveries – perfect for creating *The Sky at Night*'s August episode.

For the next fortnight all I did was watch old TV episodes until my mind was awash with images of interplanetary travel, dreams of discovering water or Martians and swirling images of Patrick Moore.

All I needed then was a location for the show's current co-presenters – Maggie and Chris – to do their thing. A quick call to the ever-helpful Airbus meant we could film in their Mars Yard – a giant sandpit in Stevenage mocked up to look like Mars, the training ground for the Rosalind Franklin rover.

Every programme always seemed to come back to the same question, 'Is there Life on Mars?' What has changed in the 55 years since Mariner IV's first fly-by of the planet – taking just 22 photographs – is what 'life' actually means. We've moved away from expectations of little green men and Martian vegetation and witnessed disappointment from Viking's failure to find microbes. More recently, Pathfinder has discovered evidence of past floods and Curiosity has revealed that Mars hosts several of the conditions needed to spark life – albeit in a rudimentary form.

Other subjects kept cropping up as well. How would we get to Mars? Could we colonise the planet? The answers here vary from the sensible – experiments in long-term space travel – to the slightly bonkers, such as a proposal for an 'easy to construct' 300km-wide annulus mirror floating around Mars to heat its surface!

Simon Winchcombe has worked in BBC Factual for the past 20 years and was series producer of *The Sky at Night* in 2018

There are also simple curiosities created by the passage of time. Patrick naturally gets older but speaks just as quickly. Computers get better but somehow less cool – in 1975, Viking scientist Gentry Lee proudly boasts of a 52lb 'brain' inside the lander with a vocabulary of 18,000 words. Then there's how the technology of EDL – entry, descent and landing – has developed to avoid the 'Great Galactic Ghoul', that mythical monster which sits in Mars orbit destroying probes (and the reason why half of all missions to Mars have failed). Even geopolitics change. When was the last time anyone compared a distance in terms of 'from here to Moscow' as Patrick did in 1969?

We may never find definitive evidence of life on Mars, but as these wonderful archive programmes show, that possibly doesn't matter. Mars isn't just a place; it's a continuing story of human exploration, of scientific and technological achievement. It's plain to see in the emotion on the faces of the teams that have successfully – or unsuccessfully – sent their spacecraft to the Red Planet over the years.

In 2019, the programme *Horizon* postulated that someone watching could be the first person to set foot on Mars's surface. Perhaps the next producer who makes a programme like this will be lucky enough to include that event.

Looking back: The Sky at Night

14 September 1985

In 14 September 1985's episode of *The Sky at Night*, Patrick Moore visited astronomer Ron Arbour, the first amateur observer in the UK attempting to track down supernovae in distant galaxies. To do so, Arbour had computerised and automated his setup – a far more challenging prospect than it is today, requiring a computer setup almost as large as the 16-inch reflector it controlled. With this system, however, he was able to image as many as 24 galaxies every night, compared to the mere six he'd been managing when observing by hand.

▲ Patrick Moore talks to Ron Arbour about searching for distant supernovae

On the night the episode was filmed, Arbour showed Patrick how his setup would automatically take pictures of several key galaxies across the sky using a specially adapted 'cold camera'. With widely available digital cameras still decades away, the setup used standard 35mm film but had a special compartment filled with dry ice to keep the film cold and increase its sensitivity.

Over 30 years later, Arbour is still hunting for supernovae and has discovered dozens – albeit with a more modern setup than when Patrick visited.

The Sky at Night SEPTEMBER

Beyond the Visible

The team find out how astronomers are learning about the Universe by looking beyond visible light. Exploring radio astronomy, the unusual sounds that space missions have captured of the cosmos and the detection of ripples in space-time known as gravitational waves, this episode is about how so much more can be detected by studying the unseen.

BBC Four, **13 September**, 10pm (first repeat BBC Four, **17 September,** 7:30pm)
Check www.bbc.co.uk/skyatnight for more up-to-date information

▲ Radio telescopes, like Jodrell Bank's, allow us to view the Universe beyond visible light

Emails – Letters – Tweets – Facebook – Instagram – Kit questions

INTERACTIVE

Email us at **inbox@skyatnightmagazine.com**

MESSAGE OF THE MONTH

This month's top prize: four Philip's titles

PHILIP'S The 'Message of the Month' writer will receive a bundle of four top titles courtesy of astronomy publisher Philip's: Ian Ridpath and Wil Tirion's *Star Chart*, Robin Scagell's *Guide to the Northern Constellations*, and Heather Couper and Nigel Henbest's *2020 Stargazing* and a planisphere for the night skies at latitude 51.5° north.

Winner's details will be passed on to Octopus Publishing to fulfil the prize

Catching Comet NEOWISE

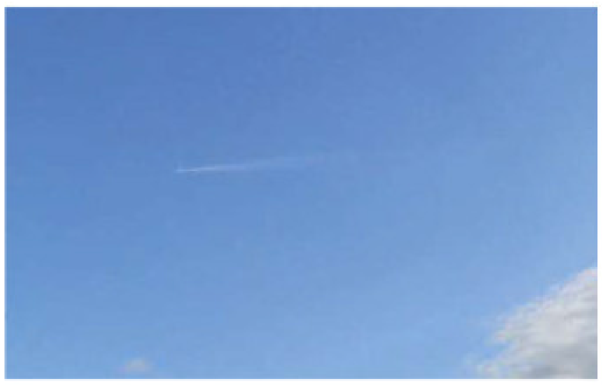
First light: Lori-Ann's wonderful shot of Comet NEOWISE

I have always found everything to do with astrophotography to be the 'here be dragons' part of amateur astronomy. I always read the articles in the magazine but never seemed to have the time to dive in and figure it out. I did finally learn all the settings on my camera last year for an aurora trip, but my long exposures still suffered from star trails. The review of the wind-up mini-tracker in the magazine a little while ago (the Omegon Mini Track LX2, October 2018 issue) – an ideal piece of equipment for someone like me, without batteries or laptops – encouraged me to get one. Then along came Comet NEOWISE and my initial photos had blurring even with a short exposure time. So I finally buckled down to figure out how to use the tracker and give it a try. This is my first night's attempt and I am pleased that it all worked as hoped. The comet head and stars are round instead of smeared out as before.

Having taken these first steps into astrophotography, I am feeling more confident and looking forward to further experiments. So thank you for all the articles on astrophotography and reviews of the equipment. It has helped one self-confessed luddite on the road to better pictures of the night sky.

Lori-Ann Foley, Jersey, Channel Islands

A wonderful picture, Lori-Ann: the stars are sharp and you've captured the comet's tail extending a nice distance from the nucleus. ***– Ed.***



Unexpected trail

I spotted this 'trail' from my kitchen. I wondered what it was and thought it might be a meteor trail. The clouds were moving right to left, so a cloud doesn't seem to fit. Do you have an idea of what it might be?

Colin Maguire, via email

An interesting observation, Colin. Meteor trails would generally point more towards the ground, however. This is more likely to be a short vapour trail left by an aircraft passing through the condensation point at that patch in the atmosphere. It could still spread in the opposite direction to lower layers of cloud, as wind direction changes with height in the atmosphere. ***– Ed.***

Going green

It is known that the colours of the stars are completely defined, which are blue, white, yellow, orange and red. Stars with a green colour or, more precisely, which appear to be green are less familiar. However, during my observations of binary stars, I noticed some amazing stellar pairs whose accompanying star tends to appear green. Examples include Gamma Andromedae, Delta Herculis, Zeta Lupi and Eta Lupi.

Khalid Alburaidi, Kingdom of Saudi Arabia

Young observations

I am an amateur astronomer and this weekend I visited my son and his family. My five-year-old grandson, Reuben, was telling me about the ISS and, somehow, we touched on black holes. He was intrigued by your story of the nearest discovered black hole ('Nearest stellar-mass black hole discovered', Bulletin, July issue) and that while the irregular motion of the double star led to its discovery, it didn't explain the

Tweets

Darren Bell
@dazdays • 13 July
A Beautiful sight in the early morning sky. #Comet #NEOWISE, photographed around 2am above the U.K. 65 million miles away, 3 miles wide and 7000 years before it's seen again, #Amazing! @newsandstar @ skyatnightmag @BBCStargazing @BBCNEandCumbria @SkyNews @itvnews @ITVborder

motion. The mystery remained. He would like to know two things. First, is it possible that the star motion is explained by a second nearby black hole? And second, what would happen if two black holes met? Can you help? We might have an astronomer on our hands!
Prof Roy Sandbach, via email

Astronomers used computer simulations to recreate the wobbling motion of the stars and a black hole in orbit was the best explanation. When two black holes meet they merge together, creating massive ripples in space time known as gravitational waves, which astronomers first 'heard' back in 2015. ***– Ed.***

A new hobby

The July edition was my first purchase of the magazine and I thought I'd try my luck at emailing in some of my first pictures. Six weeks ago I never considered astronomy, but I decided to purchase a Sky-Watcher Heritage 150P scope, ▸

ON FACEBOOK

WE ASKED: What cosmic riddle would you most like to see solved?

Laurence Blundell Einstein's theory of gravitational red shift.

Danny Castro Where did everything come from? How did matter just spontaneously materialise? I doubt we'll ever know the answer to that, but it's fun to speculate.

AR Gavin Solving the riddle over the 'Wow Signal'.

Dustin Ginetz Repeating fast radio bursts, although it is starting to look like they could be magnetars.

Adams Jon Exoplanets. In distant stars, are there or will there be the potential for advanced civilisation?

Kelvin Ong How close can we get near to a black hole?

Brian Smale Finally understanding what dark energy and dark matter are.

Joe Gathercole Linking quantum theory and general relativity with that elusive equation would be nice.

David Jones Why is it always cloudy when there is something special to see?

SCOPE DOCTOR

Our equipment specialist cures your optical ailments and technical maladies
With **Steve Richards**

Email your queries to
scopedoctor@skyatnightmagazine.com

I'm considering upgrading my Celestron 9.25 telescope with an EQ6 mount to increase my imaging capacity. What are the pros and cons I should consider before making this investment?
CLAIRE WARD

Your Schmidt-Cassegrain Telescope (SCT) and altaz mount are fine for both observing and imaging Solar System objects, but if you want to move into deep-sky imaging, a heavy-duty equatorial mount is a prerequisite and the EQ6 would be a good choice.

Another thing to consider is that although an SCT can indeed be used for deep-sky imaging – and on smaller objects like planetary nebulae it can excel – for general deep-sky imaging it does have some drawbacks. The long focal length makes tracking more difficult and extended objects like emission nebulae will be too large to fit in the field of view. There is also the risk of 'mirror flop' – movement of the primary mirror during the long exposures required for deep-sky imaging.

It would make sense to consider the purchase of the EQ6 mount as a very important stepping stone towards deep-sky imaging, but keep in mind that in the future you may want to purchase a shorter focal length apochromatic refractor for imaging.

▲ An EQ6 mount is a good stepping stone to deep-sky observing

Steve's top tip

Can I use glasses while observing?

If you are simply short- or long-sighted then wearing glasses while observing won't improve the view, as the focuser on your telescope or binoculars will do the same job as them. However, if you suffer from astigmatism there are advantages to wearing glasses, but your choice of eyepieces will be more limited. Wearing glasses puts your eye further from the eye lens of the eyepiece so you should choose eyepieces with a long 'eye relief'. This is the distance from the last lens surface of the eyepiece to the eye, which still allows the full field of view to be observed.

Steve Richards is a keen astro imager and an astronomy equipment expert

▸ some binoculars, the book *Turn Left at the Orion* and a planisphere, and I'm glad I did! Despite the weather, I snapped a few shots (above) of the Moon, Jupiter and Saturn. As an amateur astronomer of just a few weeks, I'm very pleased.
Dan Misson, Liverpool

Saturday surprise

While going through the normal nightly routine, I decided to have one last look at the night sky. It was a clear night, not much happening: the Plough looked its usual self; a few other stars were shining. Then my eyes were drawn to what appeared to be a smudge in the distance. Could it be? Time for the binoculars, and what a nice surprise. Yes, Comet NEOWISE had made its appearance over the skies in Sheffield. It was time to grab my camera. Trying to remember all the astrophotography lessons provided in the magazine I began taking photos. What was an uneventful Saturday night turned out to be one of the best!
Gary Moga, Sheffield

Instagram

nicholas_dunbar77

Managed to capture #cometneowise at stupid o'clock this morning. Had to drive about a bit to find a clear view but found the perfect spot in the end @metoffice #loveukweather #ukpotd_jul20 #gloriousbritain #thisprettyengland #excellent_britain #uk1shot #london #chingford #comet #bbcweatherwatchers @bbcskyatnightmag #bbcskyatnight

CORRECTIONS

August's news story 'Nearest brown dwarf found' (Bulletin, p13) was incorrectly titled. It should have said 'Nearest brown dwarf disc found'. The distance to the object was mistakenly listed as 332 million lightyears when it should have been 332 lightyears.

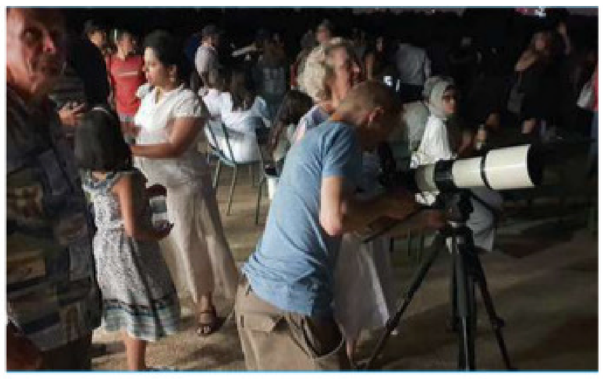
SOCIETY IN FOCUS

Following an excellent run of meetings of **The Baker Street Irregular Astronomers** (BSIA) over winter, none of us foresaw the impending upheaval of COVID-19. Our 10th anniversary was coming up in June and we were wondering how to celebrate, being the only group allowed to use London's Regent's Park after hours. We knew that we would have to suspend our meetings, as our venue – a high security Royal Park flanked by embassies – was not going to stay open.

We considered virtual meetings, but we wanted to do something different. BSIA is different from most other societies in that we draw a lot of newcomers each month to our gathering place at The Hub, often about a third of the circa 100 attendees, so we wanted to accommodate them too.

We decided to try evening YouTube sessions hosted by Irregulars (as we call ourselves) discussing their astronomy passions and these drew an audience far larger than our typical meetings. The format is very effective and popular and we will do it again soon. We're also looking to the future when normality resumes, and our eventual return to Regent's Park.

We will continue to live broadcast our meetings, opening up the world of amateur astronomy to an even wider audience who are unable to attend in person. We're fun, free and for everybody, and we hope that more will consider joining us next time.
Nicholas Joannou, committee member, The Baker Street Irregular Astronomers
▸ **www.bakerstreetastro.org**



▲ **Pre-lockdown, BSIA meetings were a busy affair in Regent's Park, London**

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COVID-19
How to get your astro fix from your own home

We pick the best astronomy events and resources available online this month

WHAT'S ONLINE

PODCASTS

13 Minutes to the Moon
Live and breathe every moment of the successful Apollo 11 lunar mission (Series 1) and the fateful Apollo 13 flight (Series 2) with this atmospheric BBC World Service podcast.
bbc.in/2W2ePWu

Reach: A Space Podcast for Kids
A weekly podcast co-created by Sandy Marshall (Solar System ambassador for NASA JPL), Reach answers kids' questions and includes fun at-home experiments. Available on most podcast platforms.

PHOTO COMP

Capture the Moon
Enter Jodrell Bank's #CapturetheMoon competition by taking a Moon photo and sharing it on social media, tagging @JodrellBank and using the hashtag #CaptureTheMoon. Be sure to include your location.

RADIO

The Privatisation of Space Travel
The Real Story's Ritula Shah discusses the private sector's designs on space with former astronaut Charlie Bolden and others.
bbc.in/31ZtXIf

CITIZEN SCIENCE

Be a solar stormwatcher
Improve our forecasting of solar storms by tracing the outlines of solar eruptions in images from NASA's STEREO mission. Solar Stormwatch II is using data from 2010–16, a period of peak solar activity, so it should make for some interesting results.
bit.ly/solarstormwatcher

PICK OF THE MONTH

▲ On YouTube, enjoy live chats and archived talks by leading experts on a range of subjects

Hubble's free public lectures

The Space Telescope Public Lecture Series goes online

The Space Telescope Science Institute (STScI), the science operations centre for the Hubble and James Webb Space Telescopes, has been serving up free public lectures from its HQ at Johns Hopkins University since 2002. That sadly came to a halt when COVID-19 struck, but they're now back in an online-only format for the rest of the year.

Each event features a noted scientist discussing a different cosmic topic, usually taking Hubble's observations as a jumping-off point. Streamed live on YouTube, there's the chance to ask your own questions via the live chat feature. If you don't catch the broadcast at the time, you can find a host of archived talks on their YouTube channel. Find one on Rubin's Galaxy, hosted by Dr Benne Holwerda who observed the massive spiral galaxy with Hubble earlier this year, and a talk by Dr Amaya Moro-Martin on 'Oumuamua, the cigar-shaped object that visited our Solar System in 2017. There's also talks on topics from black holes to gravitational waves, the key inventions behind the modern telescope, exoplanets, comets and much more.
bit.ly/hubblefreelectures

ONLINE COURSES

Learn about atmospheres
Julia Lehman, chemistry fellow at the University of Leeds, leads Atmospheric Chemistry, a free course to uncover what space missions have revealed about the conditions needed for life.
futurelearn.com/courses

GET BUILDING

Astronomy DIY
Build a smartphone holder for your telescope, make a binocular mirror mount or even an equatorial mount for a Dobsonian using one of the many *BBC Sky at Night Magazine* free online DIY guides.
bit.ly/3iNI6y0

NEW

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FIELD OF VIEW

Astronomy in times of crisis

In light of the COVID-19 lockdown we look back and see that many scientific advances have occurred during periods of hardship, at times of war or plague

Professor Fred Watson is Australia's Astronomer at Large in the Commonwealth Department of Industry, Science, Energy and Resources. Find him at **fredwatson.com.au**, @StargazerFred and in the weekly Space Nuts podcast.

The science of the stars is one of the great survivors in the COVID-19 emergency. People are facing real hardships, but there is an appetite for astronomy and space news to lighten the gloom. Astronomy clubs are reporting a growing interest in the hobby. And although many of the world's observatories are closed, and universities are struggling to keep their heads above water, researchers continue to make spectacular discoveries.

We shouldn't be surprised at the resilience of our science in difficult times. History is full of examples of its survival against the odds. Indeed, modern astronomy had its birth during a crisis, when faltering peace negotiations between Spain and the Netherlands brought a Dutch spectacle-maker's rudimentary telescope out of obscurity. A few months later, in May 1609, a chap by the name of Galileo got wind of the idea, and the rest is history.

Likewise, the two biggest advances in our understanding of the Universe had their origin in times of emergency. Isaac Newton was effectively in quarantine from London's Great Plague in 1666 when he laid the groundwork for his theory of universal gravitation – throwing in the basics of optical spectroscopy as a bonus. And Albert Einstein added the finishing touches to his own version of gravity – the General Theory of Relativity – in the dark days of November 1915.

The First World War decimated international scientific relations, but Einstein's theory went a long way towards healing the scars when it was verified by eclipse observations made in 1919 by Arthur Eddington. Global headlines trumpeted the scientific revolution wrought by a German-born physicist and an English astronomer – who were both ardent pacifists.

Interruptions to astronomical research took place during both World Wars. Major telescope projects were put on hold as manufacturers turned to gun sights, rangefinders and other 'optical munitions'. The Second World War delayed work on the giant 200-inch (5.1m) Hale Telescope at Mount Palomar, while a British company actually buried the 1.5-tonne mirror for a new South African telescope in a field to avoid possible bomb damage. Both these instruments were completed after the war, and are still at work.

Astronomers were redeployed to essential war work such as instrument design or the computation of navigational almanacs. And the development of radar during World War Two led, in a classic case of 'swords into ploughshares', to the postwar emergence of radio astronomy.

Astronomy's resilience is as important as ever today, with a new generation of immense telescopes under construction internationally. How can these benefit nations focused on containing a global pandemic? Construction contracts, technological spin-offs and international partnerships are all significant paybacks, but it is the underlying quest for knowledge that is the ultimate driver. It inspires us with the staggering beauty of the Universe and the appeal of scientific understanding. For youngsters in particular, that can prepare them for the jobs of the future, shaping a knowledge economy for a better world. And that is something all astronomers can be proud of.

OWEN DAVEY/FOLIO

A stellar nursery: Hubble's famous image of the Orion Nebula, M42, offers a peek inside a cloudy cavern where stars are forming

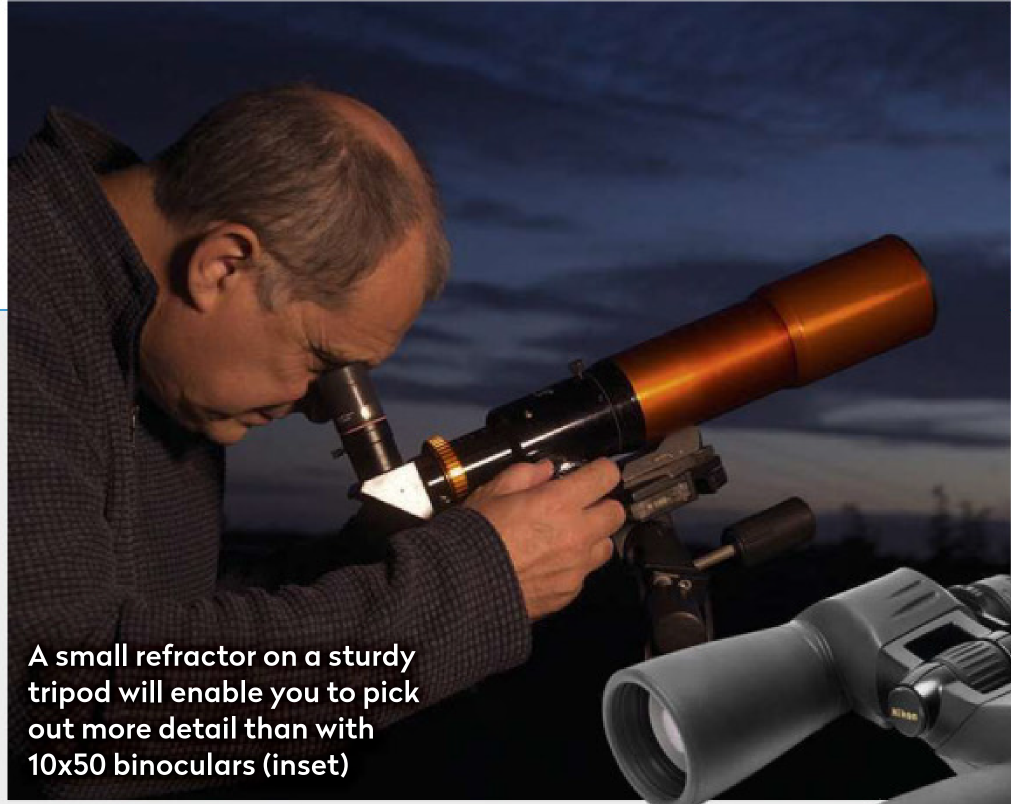
Life and death in the NIGHT SKY

The life of a star is written across our sky. **Stuart Atkinson** explains how you can see every stage for yourself

For years I've been doing astronomy outreach in schools and have heard many questions, but there was one where my own answer surprised me. While explaining how stars live and die, a youngster asked me, "How do we know that?". Looking out of the window at a nearby field, the answer came to me: "Because stars are like the sheep out there," I said. "Look... there's a young lamb jumping about, a grown-up sheep eating grass, and over there by the wall there's a dead sheep. We can see stars being born, stars that are grown up, and stars that are dying or dead, too."

The comparison works well. We know how stars are formed, live and eventually perish because the sky is strewn with stars at different stages of their lives. After centuries of joining the temporal dots we ▸

NASA/ESA/M. ROBBERTO (SPACE TELESCOPE SCIENCE INSTITUTE/ESA) AND THE HUBBLE SPACE TELESCOPE ORION TREASURY PROJECT TEAM



A small refractor on a sturdy tripod will enable you to pick out more detail than with 10x50 binoculars (inset)

Equipment guide

A simple setup should be all you need to journey through a stellar lifetime

Although many of the objects featured here are visible to the naked eye, you'll need some help to see others. A pair of 10x50 binoculars will show you the Orion Nebula as a small haze in the centre of Orion's Sword, the Ring Nebula as an out-of-focus star just beneath icy blue Vega, and the Crab Nebula as a tiny, smoky smudge a hand's width from garnet red Aldebaran. A small telescope on a steady tripod will show more detail in these objects, and observing on a Moon-free night from an observing site unaffected by light pollution will improve your views even more.

▸ now understand the evolution of stars fairly well – and you can see this process for yourself, by hopscotching across the night sky with your naked eye, binoculars and telescope.

Let's begin with the youngest of stars. All stars, regardless of how hot or large they eventually grow up to be, are born in huge clouds of dust and gas called nebulae. Our own Sun was created in one of these stellar nurseries around 4.5 billion years ago, along with other stars which have long since drifted away. As stars grow inside nebulae – becoming denser and hotter as they collect more gas and dust – they emit light and other radiation which makes the nebula glow. Many nebulae are visible in the night sky as hazy patches of light. The most famous is M42, the Orion Nebula, which shines in the centre of Orion's Sword, below his more famous Belt.

Starting with Orion

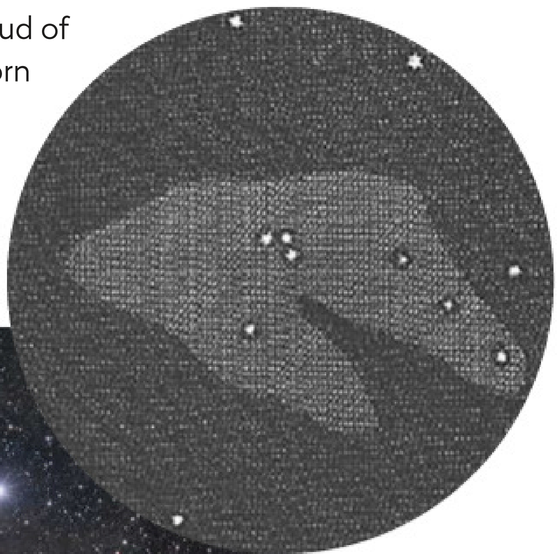
The Orion Nebula is around 1,500 lightyears from Earth and over 24 lightyears across. Binoculars show M42 as a small smudge, and small telescopes reveal a feathered cloud of grey-green with several peppercorn stars at its centre, but through a large aperture scope it is a stunning sight, with arcs and curls of bright nebulosity shining behind darker lanes and billows of dust. The Trapezium – a tight cluster of four ice blue stars – glitters at its centre.

Although M42 is mag. +4, making it clearly visible to the naked eye, it was not recorded by the early astronomers; it wasn't until 1656 that Christiaan Huygens sketched the first drawing of it (left). Long exposure Hubble images revealed around 700 young stars at the centre of M42, 150 of which are surrounded by discs of material.

It's often millions of years after their birth that young stars eventually fledge from their nebulous nests and fly free into the Universe. On dark, Moonless nights you can see many small groups of young stars scattered across the sky as if dabbed on it by a paintbrush. These are star clusters, groups of adolescent stars flying through space together like a flock of birds, bound together by gravity.

On autumn and winter nights in the Northern Hemisphere, observers can see the Pleiades, M45, the most famous star cluster in the sky. Twinkling to the upper right of Orion at mag. +1.5, this open cluster is obvious to the naked eye as a 'mini Big Dipper or Plough'. Those with good eyesight can see M45's seven brightest members, hence its nickname the Seven Sisters, although some people claim they can see as many as a dozen or more of its 500 members.

M45 lies 430 lightyears from Earth and spans around 15 lightyears. Long exposure photos show it embedded in a lacy mesh of misty blue haze. We used to think this was material left over from the



▴ A 1656 sketch of M42 by astronomer Christiaan Huygens

◂ This image reveals M42 (bottom middle) to be part of a bigger complex of stars and nebulae, which extends across the Orion constellation

CEDIC TEAM/CHRISTOPH KALTSEIS/CCDGUIDE.COM X 2, PETE LAWRENCE X 2

stars' formation, but it is actually just a cloud of interstellar dust and gas that the cluster is currently passing through.

▲ **Blue wonder: the famous open cluster, the Pleiades, M45, can be spotted with the naked eye**

Catch the Sun

As time passes on, stars continue to age. Our own Sun is a fairly typical mature star. Born in a long-gone nebula around 4.5 billion years ago, it is now middle-aged, halfway through its 10 billion-year life. We know that because we can look to other stars which are further along in their life cycles. By comparing our Sun with similar stars we can tell that it's quite comfortable in a quiet part of a quiet spiral arm out near the edge of the Milky Way, not bothering anything, just steadily burning through its supply of fuel.

Physically our Sun is an enormous ball of hydrogen some 1.3 million km across, which Earth orbits at a distance of 150 million km, taking around 365 days to do so. But even from that great distance if the Sun went out now it would be eight minutes before everything went dark. It won't die for another five billion years though, first expanding to become a huge red giant star before blowing off its outer layers and then shrinking and cooling, ending its days as a super-dense, planet-sized white dwarf.

North of the Orion Nebula shines the bright orange star Betelgeuse. At mag.+0.45, it's the second ▸

Photographing the stellar lifecycle

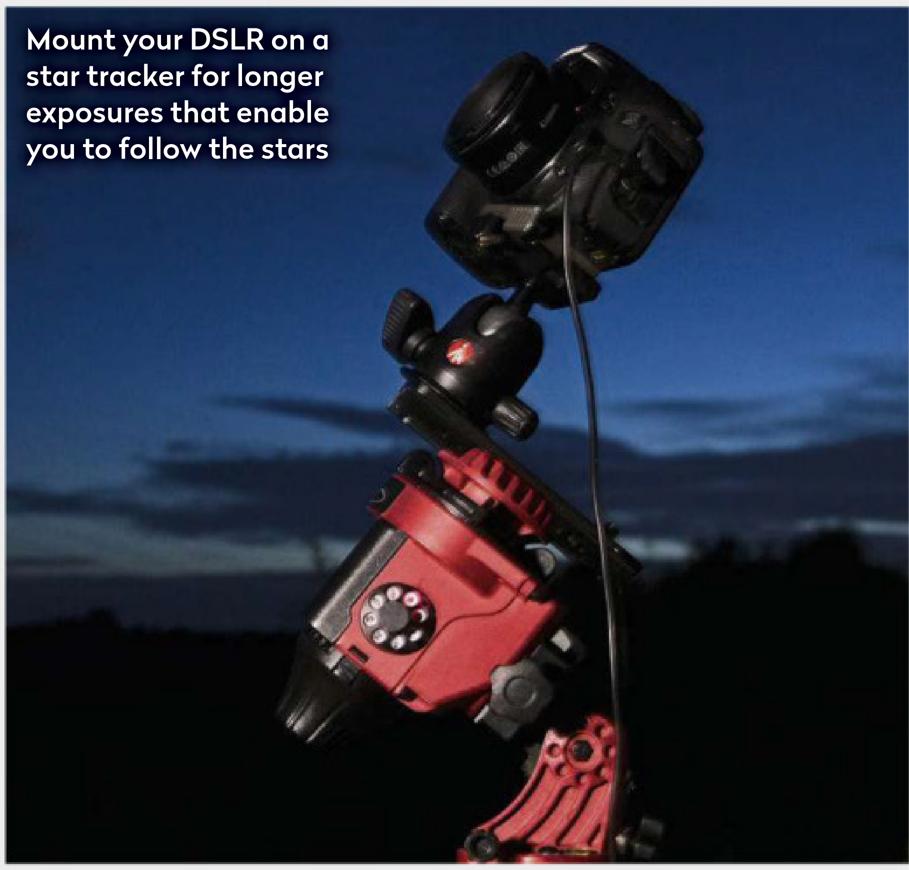
With fluid filaments painted in beautiful colours, there's plenty of photo opportunities

You can photograph every stage of a star's life with a DSLR camera and no telescope is needed. To do so you'll need to be somewhere away from light pollution, on a clear night with no Moon in the sky.

The Pleiades and Betelgeuse can be photographed with just the camera mounted on a tripod. Fitted with a standard 50mm lens, set it to take exposures of six seconds, with an ISO setting of 400 or 800.

Being smaller and fainter, the Orion, Ring and Crab Nebulae will need a longer lens. You'll need to keep the exposures short to avoid trailing, so use a higher ISO.

To take more detailed photos, using longer exposures, you'll need to mount your camera on a 'star tracker', a motorised mount that allows you to take exposures that are minutes long by following the movement of the stars across the sky. To make the objects clearer in your photos you might need to take multiple images and stack them together using special software. You can then process these images with different software to bring out detail and make them appear brighter and more obvious.


Mount your DSLR on a star tracker for longer exposures that enable you to follow the stars

ILLUSTRATION

Betelgeuse will go out in a blaze of glory. It will blow up in a cataclysmic explosion – a supernova

▸ brightest star in Orion and ninth brightest in the whole sky. About 650 lightyears from us, Betelgeuse is 135,000 times brighter than our Sun and so huge that, if it was put in its place, it would swallow up all the inner planets and the asteroid belt and extend to around Jupiter. Betelgeuse is in the twilight of its years, but unlike our own Sun, which will end its days meekly, it will go out in a blaze of glory. It will blow up in a cataclysmic explosion – a supernova.

When? We don't know. Last Christmas, when a sudden dimming of Betelgeuse saw it plummet in brightness, many excited stargazers wondered if it was about to go boom. However, the star's brightness gradually increased and it's now back to normal. So, Betelgeuse is safe – for now. One day it will explode and shine brighter in Earth's night sky than the full Moon, even becoming visible in the daytime as a bright silvery spark; something to look forward to.

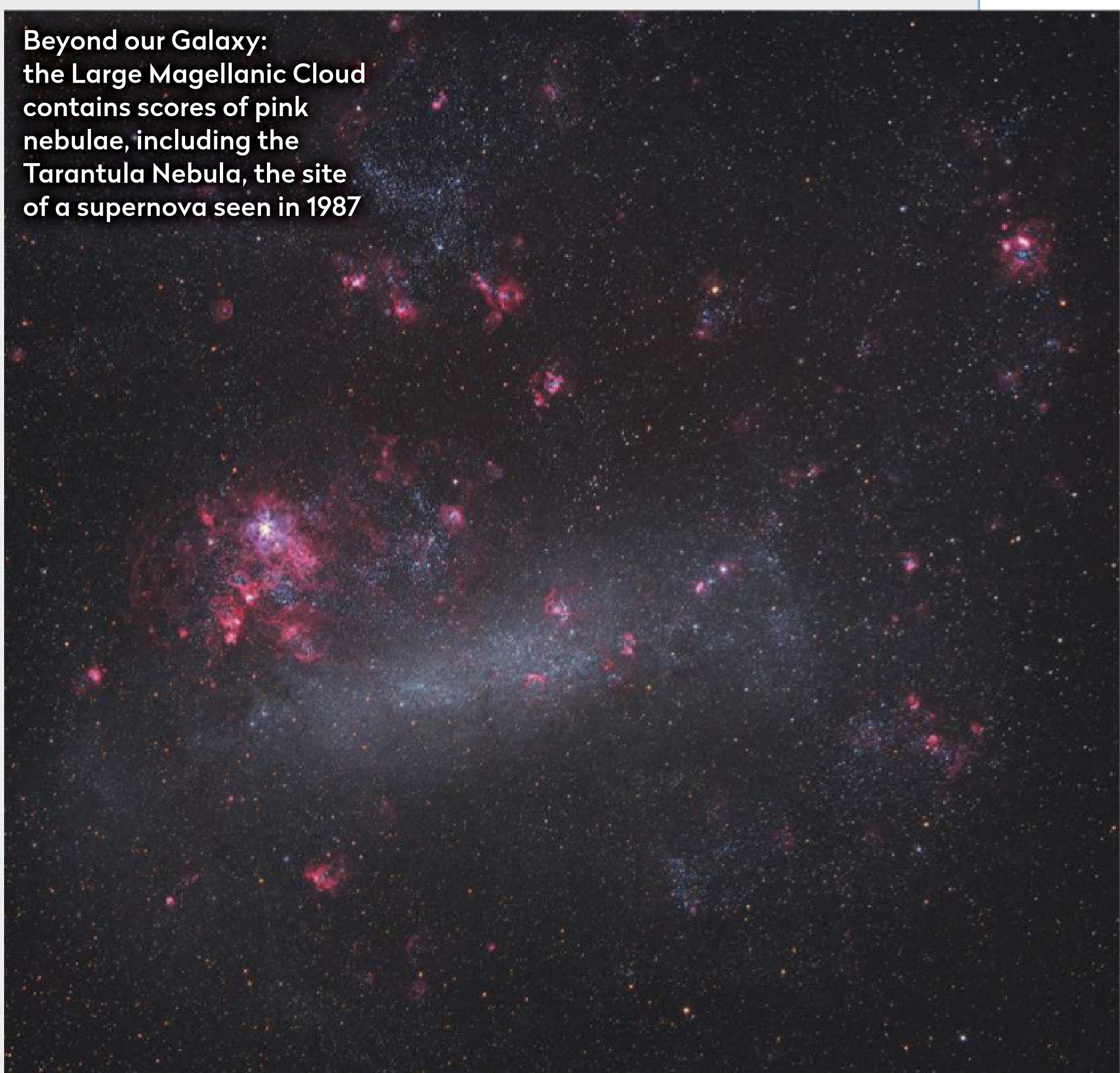
Although stars with the same mass as our own Sun don't go through all the fuss of exploding in a supernova, they do put on a show before they die. Instead of blowing up they throw off their outer layers in a number of puffy, mottled shells of coloured

The bigger picture

Astronomers aren't just looking at stars within our own Galaxy

Although astronomers could use only the nearby stars and nebulae in our own Galaxy to learn about the life cycles of stars, it's very helpful for them to look at others much further away to confirm their observations and refine their results. Using the world's largest telescopes and orbiting observatories, they have studied nebulae, star clusters and dying or dead stars out in the depths of space, in other galaxies far beyond our own.

They have found fascinating examples of all these types of objects in the Magellanic Clouds, two of the Milky Way's many satellite galaxies, and M31, the stunning Andromeda Galaxy, which is 2.5 million lightyears from Earth and much larger than our own Milky Way. These observations have helped improve our understanding of how stars are born, live and eventually die and have helped confirm that our theories of stellar evolution are correct. We are, however, constantly adding to that understanding and filling in more pieces of the puzzle by making new discoveries and new observations with more advanced imaging equipment, observing techniques and data analysing software.



Beyond our Galaxy: the Large Magellanic Cloud contains scores of pink nebulae, including the Tarantula Nebula, the site of a supernova seen in 1987

MARK GARLICK/SCIENCE PHOTO LIBRARY/ALAMY STOCK PHOTO, GERALD RHEMANN/CCDGUIDE.COM, CHRISTOPH KALTSEIS/CCDGUIDE.COM, BERNHARD HUBL/CCDGUIDE.COM

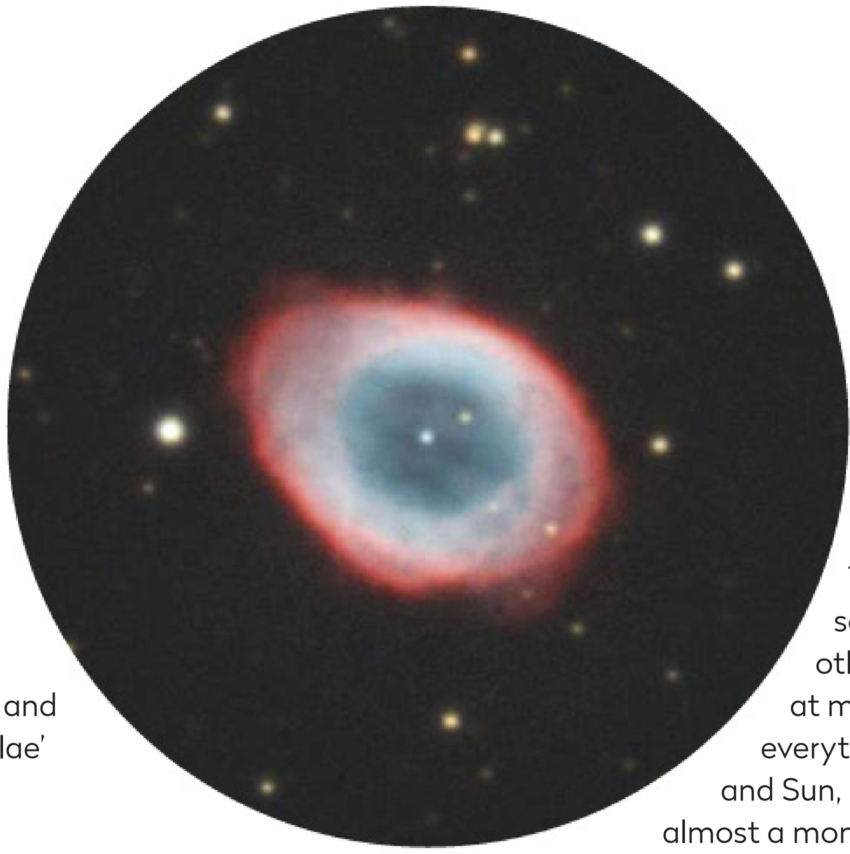
gas and dust. Seen through a small telescope these look like smoke rings or even discs, which is why when they were first seen, centuries ago, they were mistaken for planets and indeed were named 'planetary nebulae' by William Herschel.

A familiar Ring

One of the best examples of a planetary nebula can be found in the constellation of Lyra, just south of the bright star Vega. Lying around 2,000 lightyears from Earth, M57, the Ring Nebula, was discovered in 1779 by French astronomer Antoine Darquier de Pellepoix, before it was independently spotted by Charles Messier who added it to his catalogue. Through binoculars it appears to be a mag. +9.0 star with a faint green hue, though small telescopes will reveal it as a slightly lop-sided smoke ring, hinting at blue green. Larger telescopes and long-exposure photos might even be able to reveal the mag. +15 dying star at its centre. It's quite sobering to look at M57 and think that you're looking ahead in time to the death of our own Sun.

And so we reach the final stop on our tourist trail through the life of a star – the ghostly remains of a dead star, the Crab Nebula.

After dark on 4 July 1054, Chinese sky-watchers were fascinated and frightened to see a new star shining in the constellation of Taurus, the Bull. It quickly became so bright that it outshone every other star in the sky. As it peaked at mag. –6.0, it was brighter than everything in the sky other than the Moon and Sun, and it was visible in the daytime for almost a month before fading away.

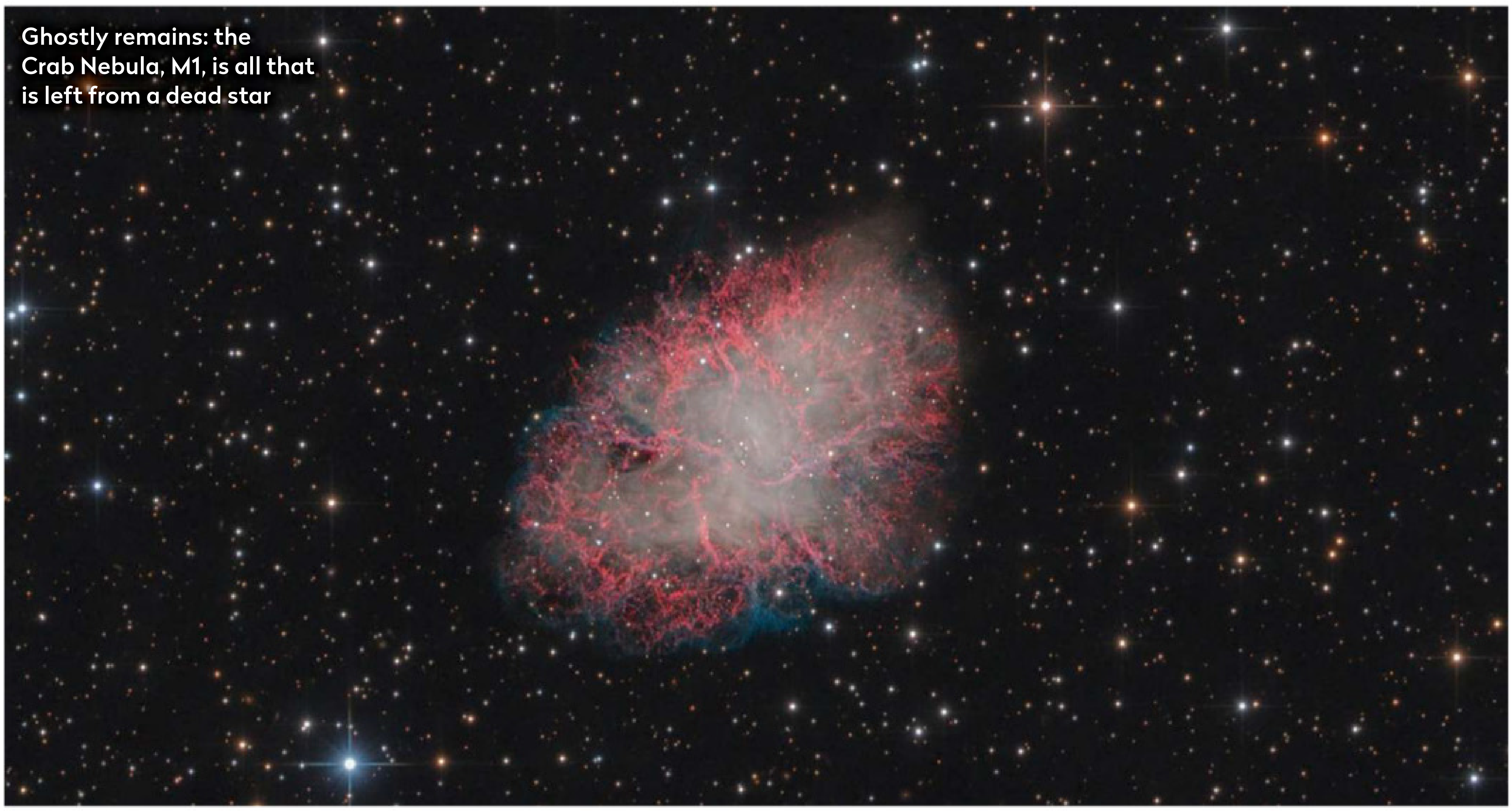


▲ A large telescope should make out the central star of M57, the Ring Nebula in Lyra

Stuart Atkinson is a lifelong amateur astronomer, public outreach educator and author of nine books on astronomy and spaceflight

Centuries later, sweeping his telescope across Taurus looking for a comet in 1758, Charles Messier saw a small, misty patch nestled in the bull's horns. Recording its location to prevent him mistaking it for a comet ever again, he designated it 'M1' and started drawing up a list of equally confusing objects that would become known as the famous Messier Catalogue, several of which we've already heard about.

Almost a century later, when Lord Rosse observed it through his Leviathan telescope from the grounds of Birr Castle, he nicknamed the ghostly patch of grey gas the 'Crab Nebula' due to its – very vague – resemblance to a crab. To modern cameras, M1 is a complicated spray of grey-green filaments. A supernova remnant, M1 is the slowly dissipating remains of a mighty star that ended its days in a supernova explosion over 6,000 years before the light of its destruction dazzled the wide eyes of those Chinese stargazers. It makes a spectacular end to our tour through the lifetime of the star.



Ghostly remains: the Crab Nebula, M1, is all that is left from a dead star

The key to unlocking DARK ENERGY

New research could help us understand the force that we think is accelerating the expansion of the Universe. As **Colin Stuart** explains, it's all to do with the number 0.007297351

There's an often-overlooked number that cosmologists believe holds the key to unlocking some of the deepest mysteries in the Universe. According to Richard Feynman: "All good theoretical physicists put this number up on their wall and worry about it." Equal to approximately 1/137, it's called the 'fine structure constant' and it describes the way light interacts with atoms. Except, according to new research, it might not be so constant after all. That in turn could help us to explain why the expansion of the Universe appears to be speeding up, and to predict the ultimate fate of the cosmos.

It was 1998 when our understanding of the Universe began to turn upside down. The cosmos has been expanding since its creation in the Big Bang nearly 14 billion years ago. Most astronomers assumed that this expansion was slowing down as the energy from that initial event petered out. Except new measurements using distant exploding stars called supernovae showed the opposite to be true. Over the last few billion years, it ▸

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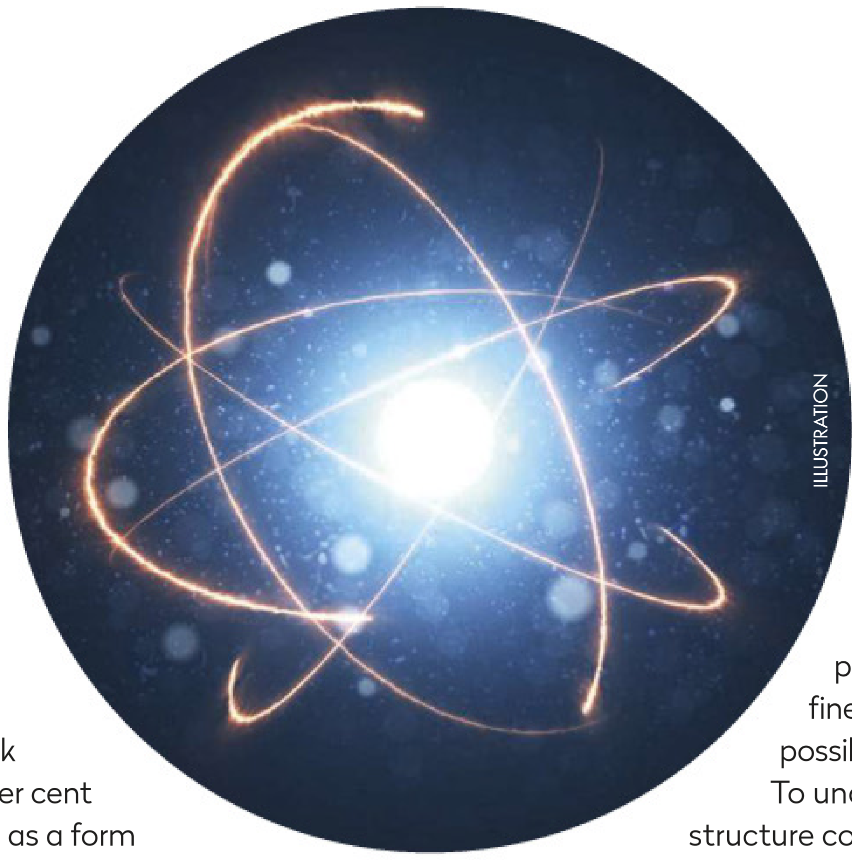
The rate of the Universe's expansion appears to be driven by dark energy, but what is this mysterious force?



▸ seems, the Universe has been growing at an ever-accelerating pace (see box, page 37).

Dark energy rush

This unexpected twist is usually put down to a shadowy entity called dark energy, which makes up around 68 per cent of all the stuff in the Universe. It acts as a form of anti-gravity and is pushing the Universe apart. But why did its influence only start to ramp up long after the Big Bang? Traditionally, dark energy has been seen as a constant. As it pushes galaxies apart, their gravitational attraction wanes; this means they find it harder to resist the effects of dark energy and the expansion quickens, weakening their attraction yet further – creating a vicious cycle. So it's not that dark energy itself is getting stronger, rather that its ability to accelerate the expansion of space is gradually ramping up.

There is another, less mainstream option. Perhaps the strength of dark energy itself has changed over the lifetime of the Universe and it's only now becoming more potent. If that's true then it would rule out the majority of the current leading theories for what dark energy is made of (see box, page 37). It's that special number – the fine structure constant – that provides a possible way to test this controversial idea.

▲ Thinking small: the fine structure constant affects electromagnetic force, which in turn affects the size of the orbits of electrons around a nucleus in an atom

To understand the significance of the fine structure constant – also known by the Greek letter alpha (α) – you need to dive inside the atom. A force known as electromagnetism – the same force that attracts the North Pole of one magnet to the South Pole of another – keeps particles called electrons whizzing around a central nucleus. The fine structure constant sets the strength of electromagnetic force, in turn dictating the sizes of the electrons' orbits. If it were stronger, for example, then the electron orbits would be crowded more tightly around the nucleus.

Yet if the strength of dark energy has changed over the Universe's history, it could have had a significant effect on the fine structure constant too. "If dark energy is not a constant then it must be some kind

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A short history of dark energy

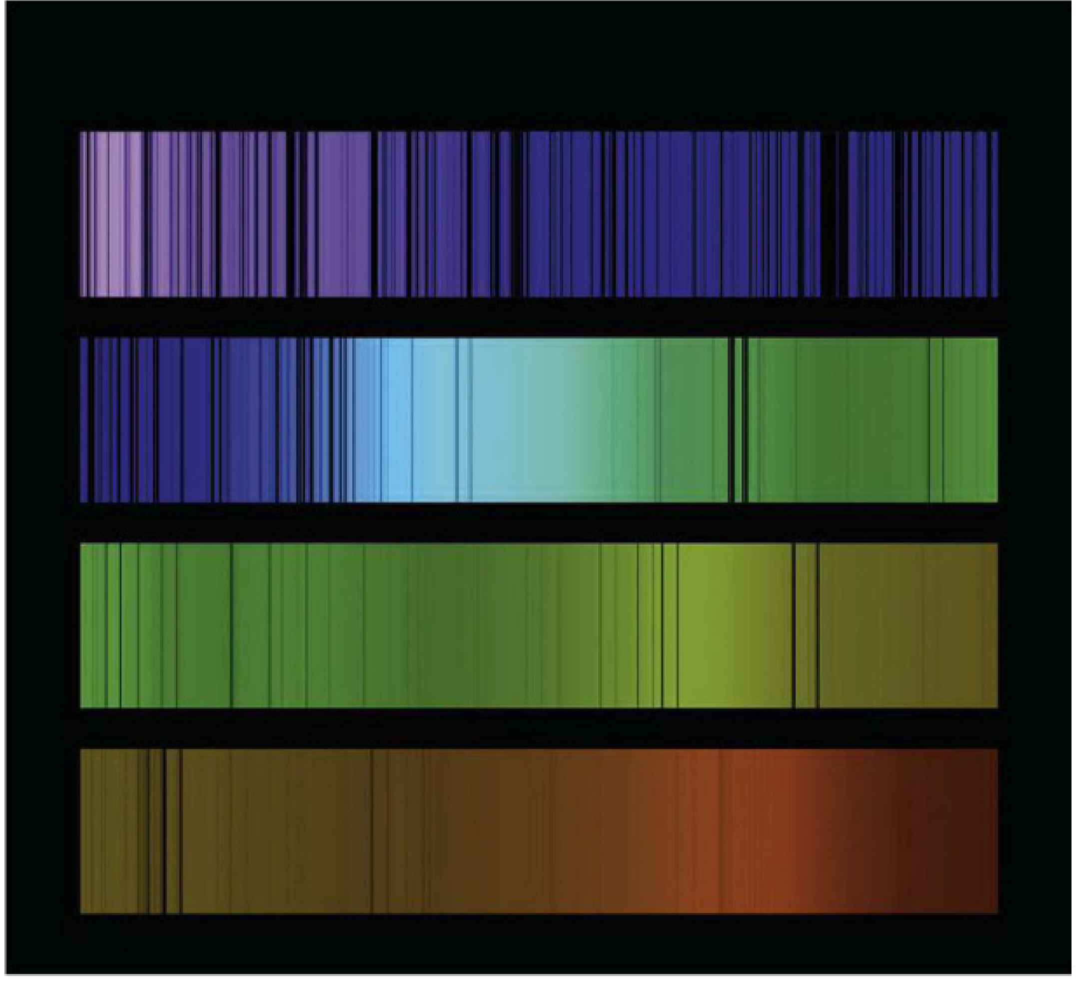
A puzzling observation 22 years ago led to today's theories of dark energy

How do we know that the expansion of the Universe has been getting quicker of late? It's based on a type of exploding star known as a Type Ia supernova. They detonate when a small, dead star called a white dwarf gorges on a nearby star until it becomes unstable. As this always happens at a similar stage, all supernovae of this type should explode with a similar brightness. This makes them great cosmic rulers, as dimmer ones must be further away.

In 1998, two teams of astronomers were racing to measure the distances to these stellar explosions. They found that Type Ia supernovae were consistently further away than they should be, suggesting the Universe had expanded more than we'd previously believed. The search for the culprit behind this accelerated expansion has remained one of cosmology's hot topics.

Three of the astronomers behind the discovery shared the Nobel Prize in Physics in 2011, but others have called the results into question, pointing out that Type Ia supernovae aren't quite the reliable yardsticks we'd thought they were.

Type 1a supernovae have helped scientists research the accelerated expansion of the Universe



of field," says Carlos Martins, from the University of Porto. In physics, a field is a region over which a force has an influence – for example the Earth's gravitational field. The dark energy field would in turn affect the electromagnetic field within atoms. "The two fields are so interconnected that a change in one triggers a change in the other," says Martins. "In any model in which dark energy varies, you unavoidably expect some variation in the fine structure constant." In other words, find that alpha varies and you can be confident dark energy varies too. "Traditional models of dark energy don't produce variations in the fine structure constant," says Rubén Arjona from the Autonomous University of Madrid.

▲ Quasar spectroscopy is being used to analyse the value of the fine structure constant in data from some of the earliest galaxies...

▼ ...with Quasar J1120+0641 pushing the measurements back to 13 billion years ago

Significant number

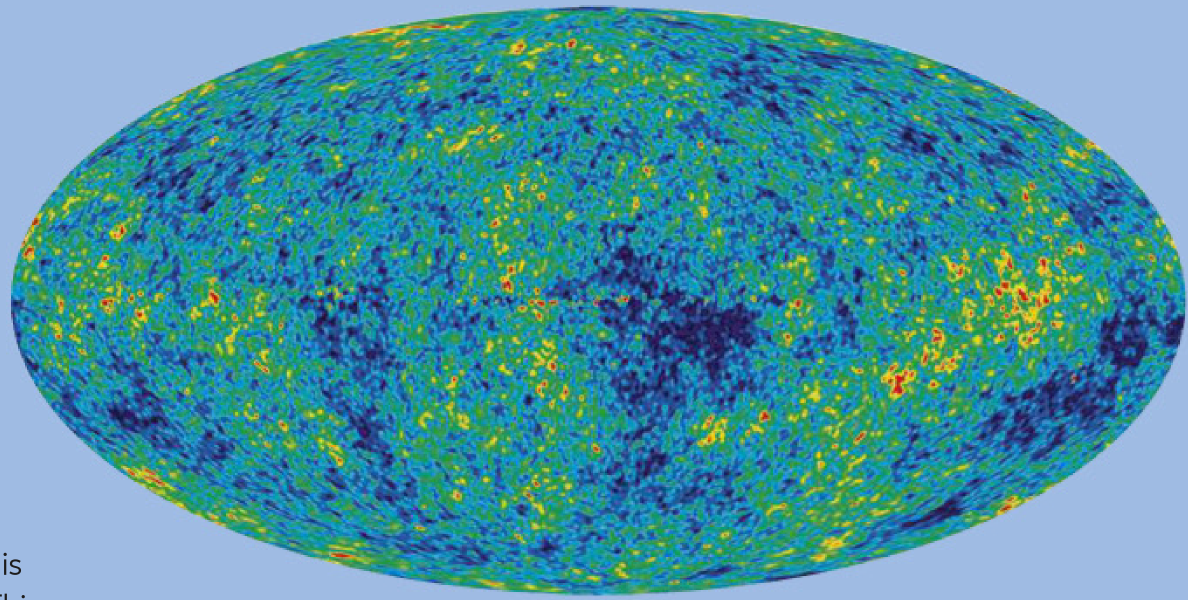
The value of alpha can be exquisitely measured in a laboratory here on Earth, making it one of the most accurately determined numbers in physics. It is equal to 0.007297351, give or take 6 on that last digit. According to research published in February it can even be measured by looking at the signals pinging between our satellite navigation systems. To see if alpha maintains this value across the vastness of space you need some way of measuring it far across the Universe, and this is where quasars come in. Their name is a contraction of 'quasi-stellar object' and they look like stars, but in fact they are the bright cores of some of the first galaxies to form. "We can use them to reach back to within 800 million years of the Big Bang," says John Webb, from the University of New South Wales in Sydney, Australia.

The key is to look for ancient quasar light that has passed through a nearby cloud of gas and dust before setting out on the long trek to Earth. Astronomers use a device called a spectrometer to break the light up into a spectrum of its constituent colours – a bit like a raindrop splitting sunlight to create a rainbow. The otherwise colourful spectrum is full of dark, black bands known as absorption lines. These are simply colours that are missing because electrons in the gas cloud swallowed that part of the quasar's light, using it to jump up to a higher orbit around the atom's nucleus. If the fine structure constant was different back then, so was the size of that jump. That means a different part of the light will be missing and the black absorption line will appear in a slightly different part of the spectrum.

This is exactly the sort of experiment that astronomers have been performing for the last few years, with tantalising results. Their findings suggest that the fine structure constant was different in the past. Then, in April this year, John Webb and his colleagues published four measurements of a single quasar – J1120+0641 – pushing measurements of alpha back to 13 billion years ago. "That's half as far again as any previous measurement," says Webb. When combined with existing quasar data, these new results support the idea that alpha differs from its Earthly value by two parts in 100,000. "It is a very tentative result, but it is also very suggestive," says Webb.

To put this work on firmer ground we need to make more quasar observations and that's already in the pipeline in the months and years ahead. "There are 30 more known quasars that we can study at the moment," says Webb. An upcoming instrument – the European Extremely Large Telescope (E-ELT) will be ▸

ILLUSTRATION



▸ well suited to studying them in this way when it sees first light in 2025. It will be positioned in the Atacama Desert in Chile, 20km from the existing Very Large Telescope, which Webb used to make his potentially revolutionary quasar measurements. "This topic is one of the drivers for building the E-ELT," says Webb. Carolos Martins agrees that it will be game-changer for this field of enquiry. "It will have a huge impact," he says.

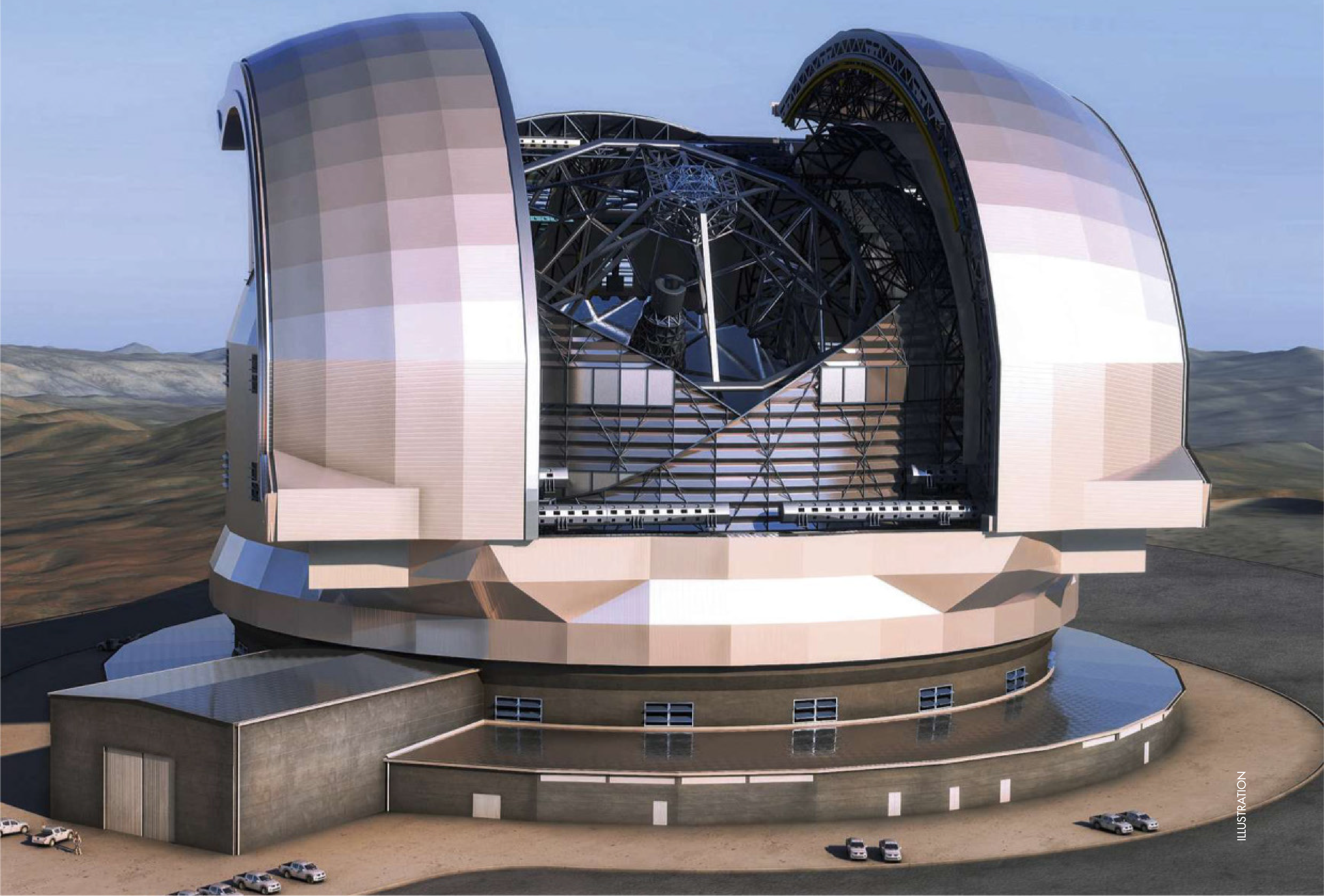
In the meantime, Rubén Arjona has been measuring alpha when the Universe was a few billion years old by analysing the cosmic microwave background (CMB), the left-over radiation from the Big Bang. A map of this radiation (see above) is riddled with speckles – tiny spots that are slightly hotter or cooler than the background temperature. Variations in alpha would have an effect on these speckles. Usually you have to base your analysis of the CMB on a particular theory of dark energy to account for how much the Universe has expanded. However, Arjona used a technique called machine learning, where computer algorithms look for patterns in the data instead. "One of the advantages of using machine learning is that you don't have to assume any dark energy model," he says. "It ensures you're not biased." His work, published in February, found no variation in alpha and is consistent with dark energy being constant.

▲ Scientists have used the cosmic microwave background (CMB), a map of radiation left from the Big Bang, to research dark energy

▼ When built, the E-ELT (European Extremely Large Telescope) will be a game-changer in furthering our understanding of the Universe

Looking at our Galaxy's heart

Other astronomers have been probing the variability of alpha even closer to home, in our own Galaxy. A team led by Aurélien Hees from the Paris Observatory has been scrutinising the stars orbiting Sagittarius A*, the supermassive black hole at the heart of the Milky Way. Their work was published in February. "It's the first time variations in alpha have been looked for around such a compact object," he says. In contrast to the quasar observations, Hees found no evidence that



Scientists have been scrutinising stars around our Galaxy's supermassive black hole for a variability in alpha

If dark energy is constant, as traditional models would have it, then its influence grows uncontrollably as the Universe expands. This would lead to what astronomers call the 'Big Rip'

alpha varies from its Earthly value. "If any variation is there it must be smaller than one part in 100,000," he says. Otherwise he'd have seen it.

Where will it all end?

So what does this all mean for the fate of the Universe? It could – and that's a big could – stop us all being ripped apart. If dark energy is constant, as traditional models suggest, then its influence grows uncontrollably as the Universe expands. This would lead to what astronomers call the 'Big Rip'. Eventually, even the space between and within atoms is stretched to such an extent that they are torn apart. The Universe becomes an empty sea of shrapnel. No stars, planets, life forms or even atoms. This could all happen in as little as 22 billion years.

Yet if dark energy and alpha have varied over the Universe's history – as these results suggest – there is a glimmer of hope. "It makes the future harder to predict," says Martins. "The acceleration of the Universe could stop or speed up." Only by building giant telescopes like the E-ELT will we know once and for all if we're being granted a stay of execution, or whether the lights will go out on this Universe sooner rather than later.

Colin Stuart (@skyponderer) is an astronomy author and speaker. Signed book are available from *colinstuart.net/books*

Dark energy, what could it be?

The best current explanations for the Universe's accelerating rate of expansion

The most widely held answer is something called the **cosmological constant** (known by the Greek letter lambda, Λ). It originally appeared in Einstein's general theory of relativity as a way to counteract gravity and keep his notion of a static Universe that isn't expanding. Once Edwin Hubble showed the Universe was indeed expanding in 1929, Einstein labelled his cosmological constant "the greatest blunder of my life". Yet the idea gained renewed traction after the discoveries of 1998 hinted at the presence of dark energy. At its heart is the idea that even empty space contains energy and the more that space expands the more this energy dominates. It has had the same value everywhere in space throughout the Universe's history.

Quintessence is the other leading dark energy contender. It says that dark energy is in fact a substance that pervades space, rather than a property of space itself. Its name means 'fifth essence' as it would be the fifth different component in the Universe after ordinary matter, light, particles like neutrinos and dark matter. Unlike the cosmological constant, the outward pressure exerted by quintessence can evolve over time – which explains why the Universe's expansion has only started to accelerate relatively recently.

Big question: is dark energy a property of space itself?

BBC Sky at Night MAGAZINE

16-PAGE STARGAZING GUIDE

The Sky Guide

SEPTEMBER 2020

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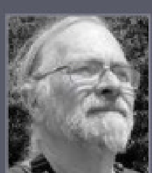
About the writers

Astronomy expert **Pete Lawrence** is a skilled astro imager and a presenter on *The Sky at Night* on BBC Four



Steve Tonkin is a binocular observer. Find his tour of the best sights for both eyes on page 50

Also on view this month…

✦ Venus appears with a crescent Moon and M44

✦ Discover Scheat in the Great Square of Pegasus

✦ Get to know the lunar crater Purbach

Red light friendly

To preserve your night vision, this Sky Guide can be read using a red light under dark skies

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SEPTEMBER HIGHLIGHTS

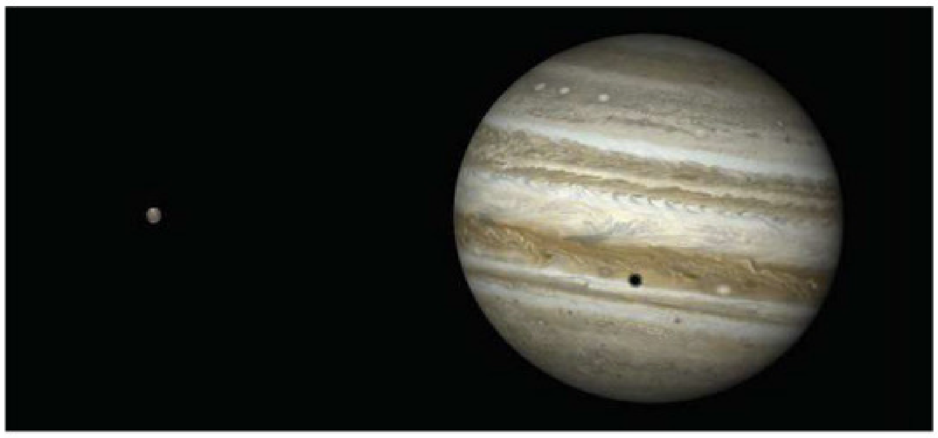
Your guide to the night sky this month

Wednesday 2

This morning's full Moon occurs when it's near apogee, the position in its orbit when it's farthest from Earth (this is on 6 September). As a result, the full Moon will be one of the year's smallest in terms of apparent diameter; unofficially known as a Micromoon.

Wednesday 9

The weak September Epsilon Perseid meteor shower reaches its peak with a maximum zenithal hourly rate (ZHR) of 5.0 meteors per hour.



Saturday 12

Catch Jupiter through a scope in the early evening and view the second half of a Ganymede shadow transit. Its shadow is on the mid-line of the planet at 21:00 BST (20:00 UT), with the transit ending at 22:55 BST (21:55 UT).

Sunday 13

This morning, bright Venus, shines at mag. –4.0 and will appear a couple of degrees south of the Beehive cluster, M44. This famous cluster is best seen through binoculars and lies at the heart of Cancer.

Tuesday 15

With the Moon slipping out of the way, it's a good time to start hunting for the planetary nebulae that are the targets of our Deep-Sky Tour on page 52.

Wednesday 16

This morning there's a chance to spot a thin waning crescent Moon. It can be seen rising above the east-northeast horizon around 05:15 BST (04:15 UT). If you manage to spot it, you'll be looking at a 2%-lit crescent.

Family stargazing

Mars is bright and now rather obvious as it rises in the east. Colours in astronomy are often subtle so this month, as Mars starts to get bright, ask your young observers to describe its colour. If you have a set of coloured pencils or pens, ask them to pick the colour that most closely matches it. Alternatively, if you have access to a computer with a graphics program, ask them to select the colour they saw using this. The colour is often described as being close to salmon-pink and occurs because the Martian surface has a lot of iron-oxide; Mars is basically rusty! **www.bbc.co.uk/cbeebies/shows/stargazing**

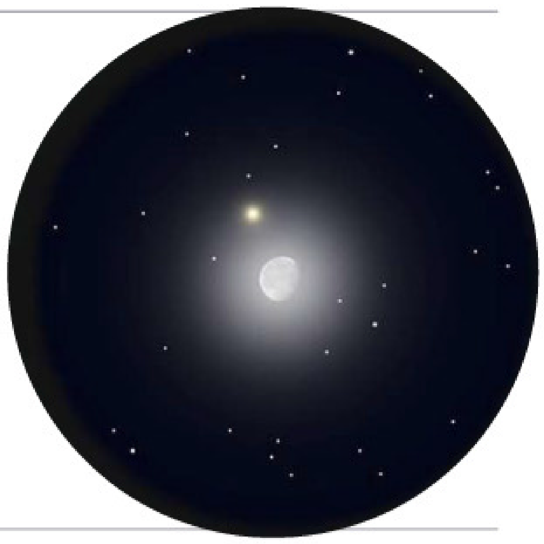
Tuesday 22

Today the centre of the Sun crosses the celestial equator at 14:30 BST (13:30 UT), marking the instant in time known as the Northern Hemisphere's autumn equinox.

PETE LAWRENCE X 9

Saturday
5 The Moon sits less than 4° from mag. –1.9 Mars as they rise above the eastern horizon around 21:30 BST (20:30 UT).

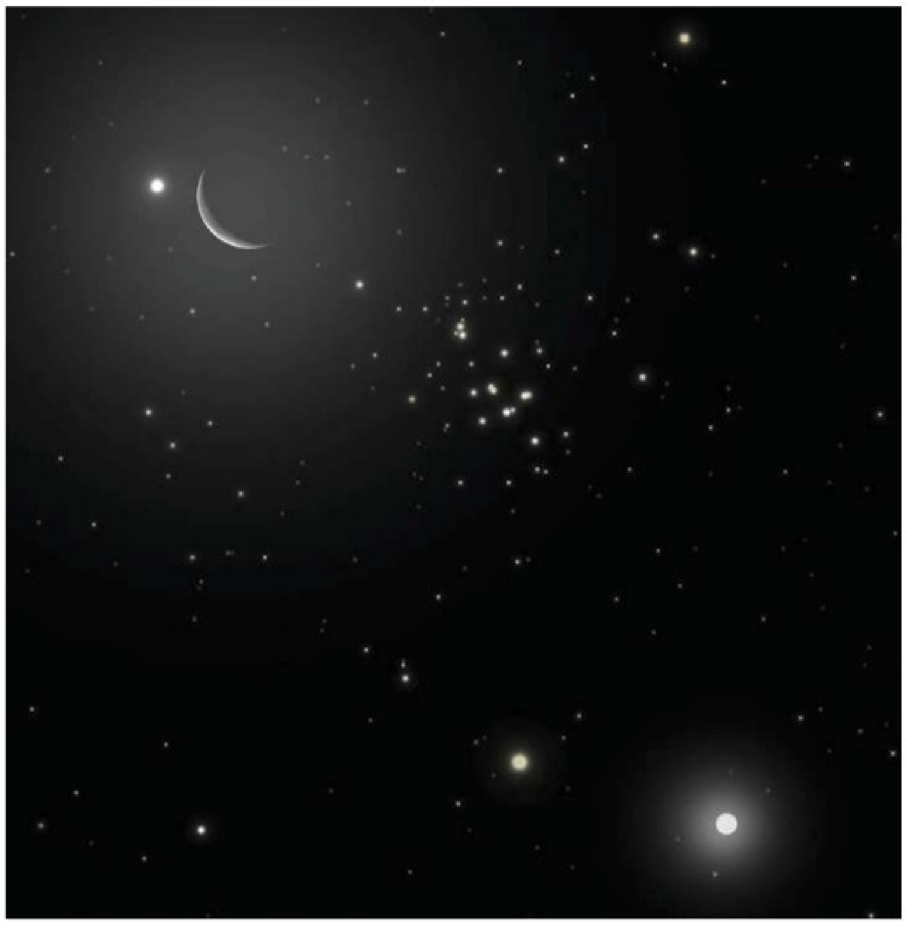
Sunday ▶
6 The apparent distance between the Moon and Mars continues to shrink this morning. Before sunrise, around 06:30 BST (05:30 UT), centre-to-centre both objects will be less than half a degree apart.



Thursday
10 The apparent movement of mag. –2.0 Mars against the background constellations comes to a halt today, a position known as a stationary point. See page 44.

◀ Friday
11 Neptune reaches opposition in the constellation of Aquarius, the Water Bearer. The planet will shine at mag. +7.8 and you'll need binoculars or a small scope to see it.

Monday ▶
14 This morning Venus and M44 are joined by a 14%-lit waning crescent Moon. At 04:00 BST (03:00 UT) the centre of the Moon sits 1.5° north of M44 and 3.8° north of Venus.



Friday
18 This evening, for a short time low above the western horizon, there'll be a thin and hard-to-spot waxing crescent Moon potentially visible, 20 minutes after sunset.

Thursday
24 The Moon reaches its first quarter phase today. Using a telescope, see if you can spot the profile of a human face outlined by the rim shadow of crater Albategnius; this clair-obscur effect is the Face in Albategnius.

◀ Friday
25 This evening there's another clair-obscur effect visible on the Moon with a scope. At 22:00 BST (21:00 UT) the crater Clavius will be in darkness, apart from the rims of two craters which lie within. This spooky effect is known as the Eyes of Clavius.

NEED TO KNOW

The terms and symbols used in *The Sky Guide*

Universal time (UT) and British Summer Time (BST)
Universal Time (UT) is the standard time used by astronomers around the world. British Summer Time (BST) is one hour ahead of UT

RA (Right ascension) and dec. (declination)
These coordinates are the night sky's equivalent of longitude and latitude, describing where an object is on the celestial 'globe'

Family friendly
Objects marked with this icon are perfect for showing to children

Naked eye
Allow 20 minutes for your eyes to become dark-adapted

Photo opp
Use a CCD, planetary camera or standard DSLR

Binoculars
10x50 recommended

Small/ medium scope
Reflector/SCT under 6 inches, refractor under 4 inches

Large scope
Reflector/SCT over 6 inches, refractor over 4 inches

GETTING STARTED IN ASTRONOMY
If you're new to astronomy, you'll find two essential reads on our website. Visit **http://bit.ly/10_easylessons** for our 10-step guide to getting started and **http://bit.ly/buy_scope** for advice on choosing a scope

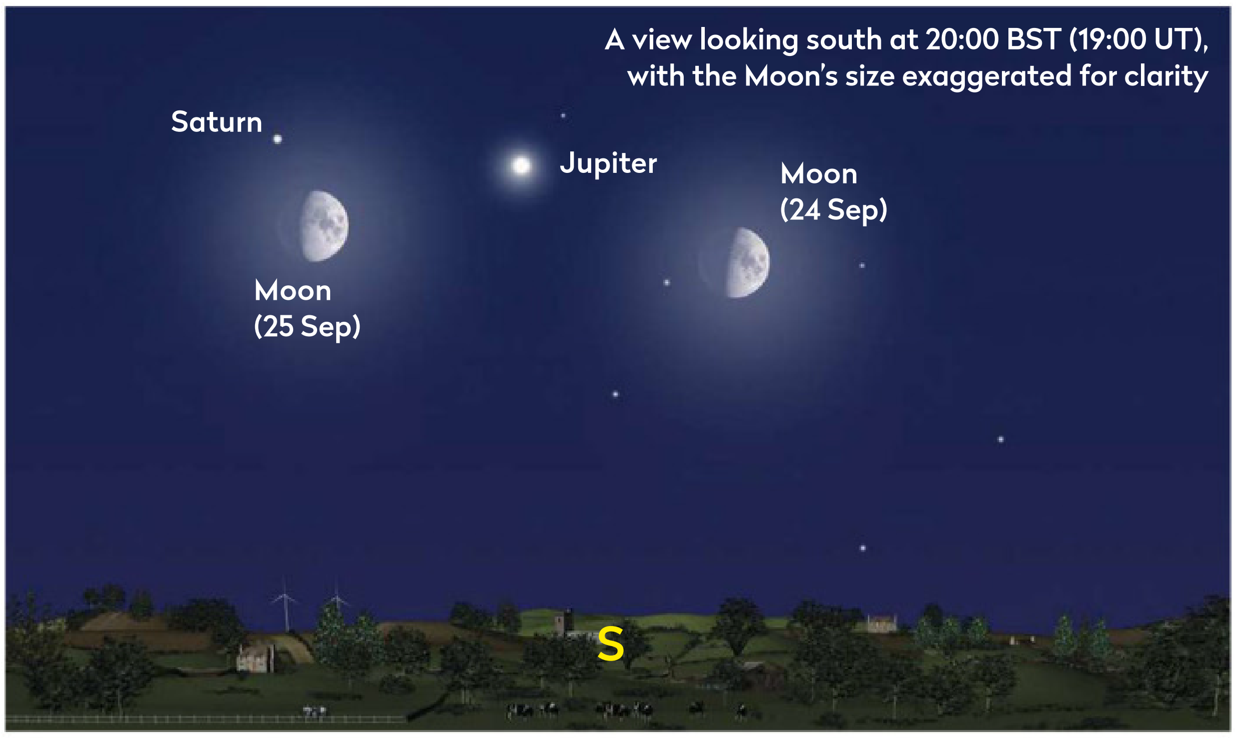
DON'T MISS

A month for CONJUNCTIONS

BEST TIME TO SEE:
6, 14, 18 & 25 September

There are many different ways to define a coming together of two or more heavenly bodies in the sky. The general term for this is a conjunction and it's often used to describe objects appearing close together or having a minimal separation. It can also refer to objects having similar ecliptic longitudes or equatorial right ascensions.

This month there are several interesting conjunctions, beginning with a close encounter between the Moon and Mars. As Mars is approaching opposition, it currently appears bright in the sky. At 04:00 BST (03:00 UT) on 6 September, mag. –1.9 Mars appears due south, and 1.3˚ from an 86%-lit waxing gibbous Moon. As the morning progresses, the apparent distance between both worlds reduces so that by 06:00 BST (05:00 UT) they appear 0.6˚ apart. If the weather is clear, try to stay with them into the day. At 07:00 BST (06:00 UT) with the Sun up, binoculars or a telescope should still be able to show Mars just 11 arcminutes north of the Moon's northern limb.

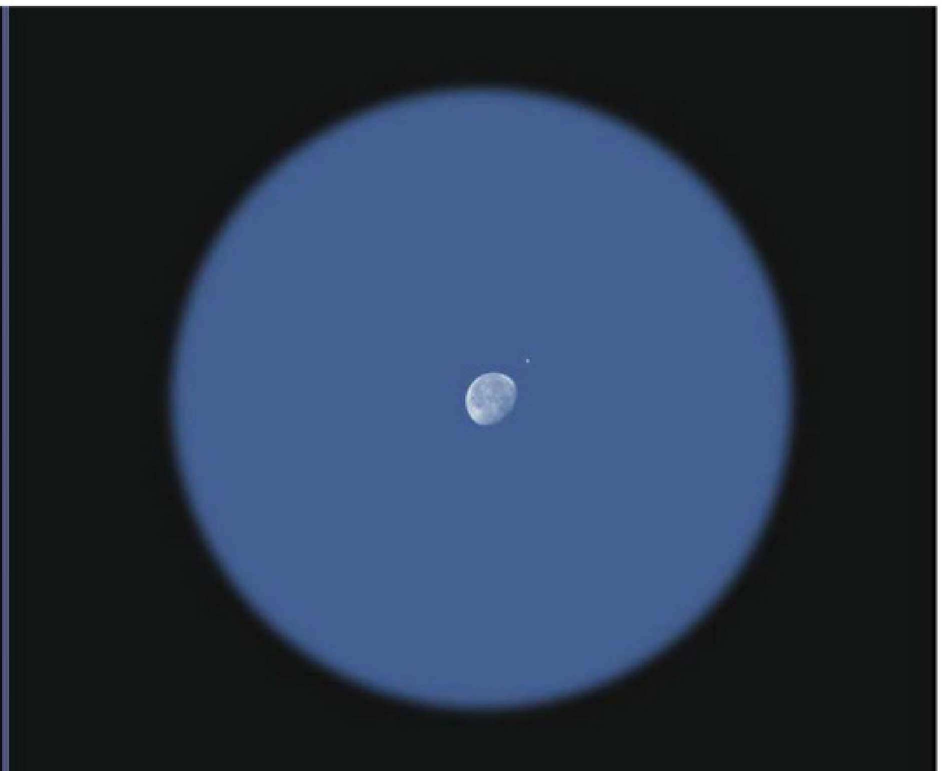


On 14 September, the apparent movement of the Moon will have it located further east and close to the brilliant planet Venus. Shining at mag. –4.0, Venus will be hard to miss in the early hours. At 05:00 BST (04:00 UT) the 14%-lit waning crescent Moon will sit 3.8˚ north of Venus. As an added bonus, just before the morning dawn, look out for the stars of the Beehive Cluster 1.6˚ south of the Moon (see opposite).

On 18 September, there's a tricky meeting between a 2%-lit waxing crescent Moon and mag. 0.0 Mercury. You'll need a flat western horizon for this pair though as they will be extremely low.

On the 24th and 25th, it's the turn of the gas giants Jupiter and Saturn to get a visit from the Moon. Both planets themselves are coming together for what's known as a 'Great Conjunction', which is set to occur on 21 December. Currently they appear slightly under 8˚ apart. On the evening of 24 September, both planets form a bent line with a 57%-lit waxing gibbous Moon, located 6.5˚ west of mag. –2.3 Jupiter at 21:00 BST (20:00 UT). The next evening, the now 68%-lit Moon will appear further to the east, forming an equilateral triangle with Saturn and Jupiter.

The Moon and Mars through binoculars: 6 September at 04:30 BST (03:30 UT)



The Moon and Mars through binoculars: 6 September at 07:00 BST (06:00 UT)

▲ On 6 September, observe Mars in the early morning close above the Moon and follow its path into daylight when it will still be visible

ALL PICTURES: PETE LAWRENCE

Venus and the Beehive

BEST TIME TO SEE: 11–15 September from 03:30 BST (02:30 UT)

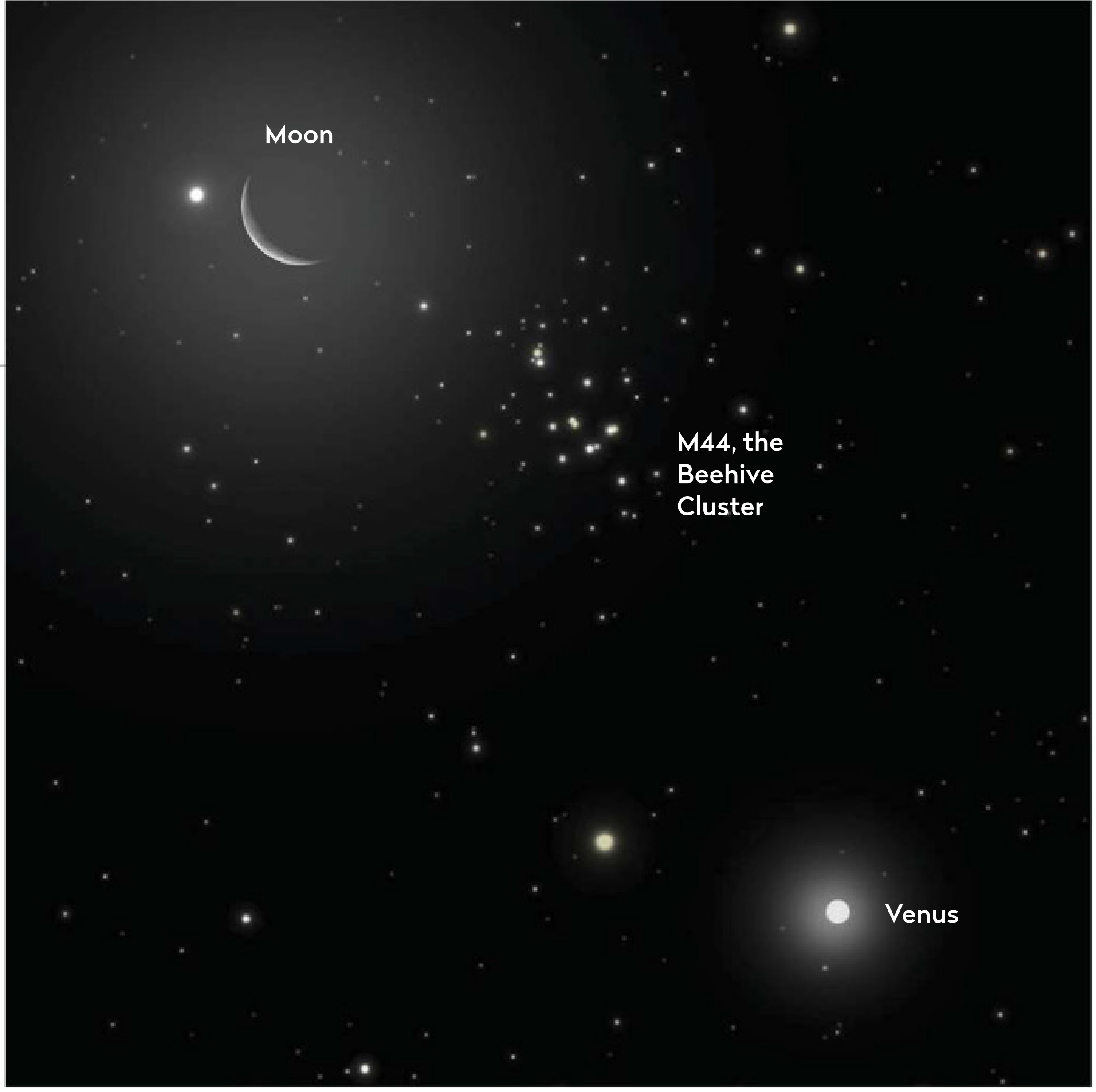
Beautiful Venus was a stunning evening twilight object for much of the first half of 2020. On 3 June, it lined up with the Sun, reaching a position known as inferior conjunction. This placed it in line with the Sun on the earthward side of its orbit. It then rapidly re-emerged into the morning sky where we find it this month.

On 1 September, Venus is located near to the twin stars Castor (Alpha (α)) and Pollux (Beta (β) Geminorum). It rises two hours before the end of astronomical darkness and shines at around mag. –4.0 for much of the month. A telescope shows its 19 arcsecond disc to be 59% illuminated on 1 September, reducing in size to 15 arcseconds and 71% illuminated by 30 September.

Between 11 and 15 September, Venus passes south of the beautiful Beehive Cluster, M44, which is located at the heart of Cancer, The Crab. On 11 September, the planet lies 3.3˚ to the southwest of the Beehive's centre. This reduces to 2.6˚ on 12 September and 2.3˚ on 13 September when both objects appear at their closest.

On the mornings of 14 and 15 September, Venus gradually nudges further to the east ending up 1.2˚ southeast of mag. +3.9 Delta (δ) Cancri on the morning of the 15th. A thin 14%-lit waning crescent Moon likes just north of the Beehive on the morning of the 14th.

Any of these morning views will provide an interesting opportunity to record the pair, both with binoculars, a wide-field telescope or photographically. Continuing its movement east, Venus will eventually end up in Leo, close to the star Regulus (Alpha (α) Leonis). The pair are set for a very close conjunction on the morning of 3 October, appearing just 12 arcseconds apart on that date.



▲ **Venus and a 14%-lit waning crescent Moon near M44 on the morning of 14 September**

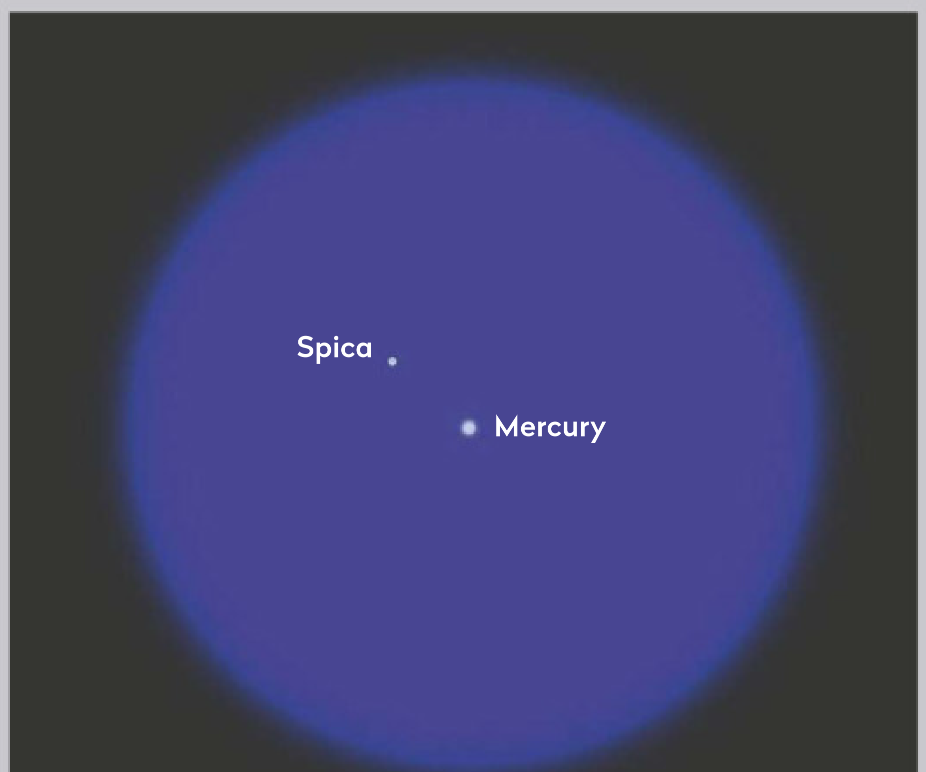
Mercury near Spica during the day

BEST TIME TO SEE: 22 September at 14:30 BST (13:30 UT)

On 22 September, mag. 0.0 Mercury lies due south at 14:30 BST (13:30 UT), attaining an altitude of 26˚ from the centre of the UK. At this time, it's 0.3˚ northeast of mag. +1.0 Spica (Alpha (α) Virginis). Despite being daylight, given clear skies it may still be possible to see both planet and star. The easiest way to locate them in daylight is to offset from another astronomical object, in this case the Sun. Precautions must be used in order to do this.

A telescope on an aligned equatorial mount with setting circles can be used. The telescope must be filtered using a full aperture certified solar filter. Finders must be capped or filtered too. Centre on the Sun and set the setting circles to the Sun's co-ordinates, then offset to Mercury. Ensure the scope isn't pointing at the Sun before removing the filters or caps. As a double-check, the scope should be pointing east (left) of the Sun.

At 14:30 BST on 22 September the Sun's co-ordinates are RA 11h 59m 00s, dec. +00˚ 06 minutes 36 seconds. The RA of Mercury will be 13h 26m 18s, dec. –10˚ 59 minutes 42 seconds. Apps or planetarium programs such as Stellarium can be used to give the positions at other times of the day.



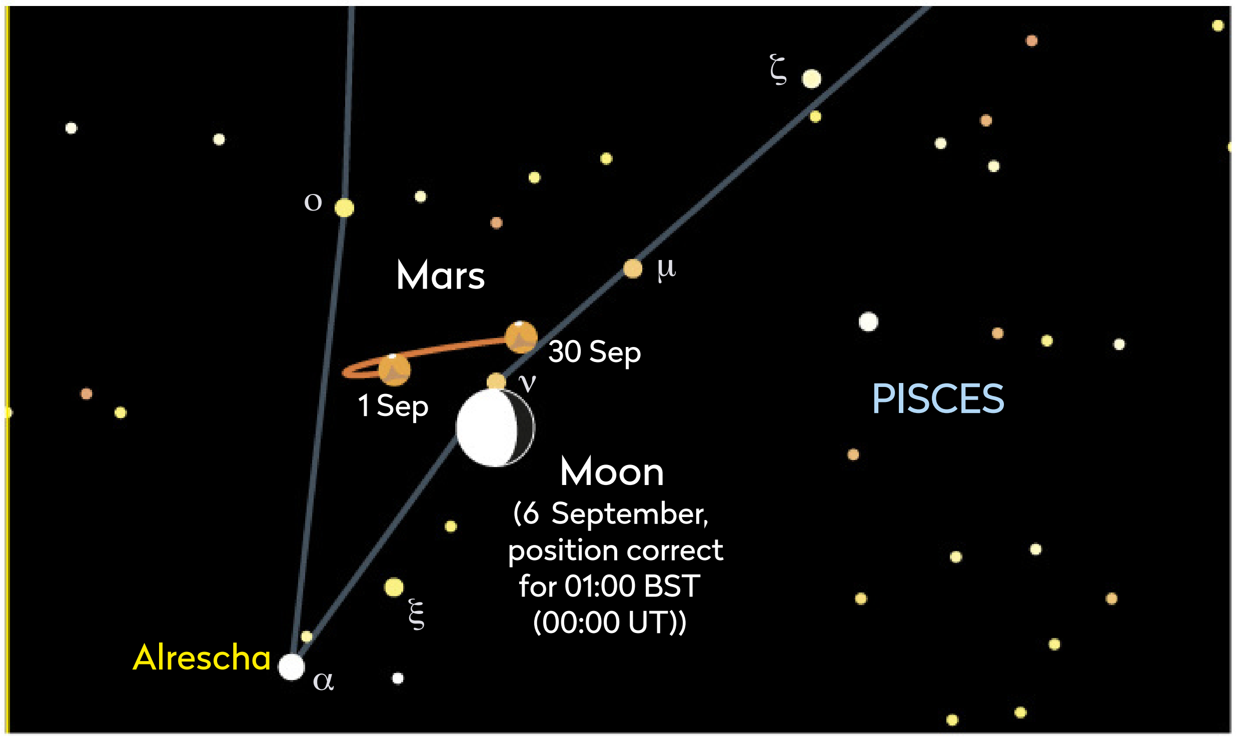
Mercury and Spica, as they appear through a telescope eyepiece at x25 on 22 September at 14:30 BST (13:30 UT)

THE PLANETS Our celestial neighbourhood in September

PICK OF THE MONTH

Mars

Best time to see: 30 September, 02:00 BST (01:00 UT)
Altitude: 43˚
Location: Pisces
Direction: South
Features: Dark 'albedo' features, polar caps, weather
Recommended equipment: 150mm or larger



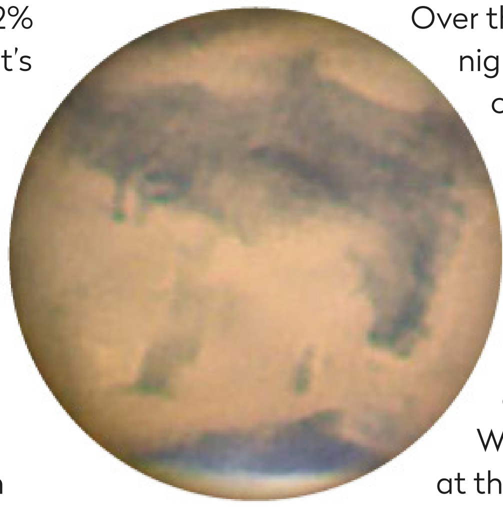
▲ During the course of September, Mars will appear to increase in size by about 22%

Mars now dominates the night sky, its gorgeous salmon-pink colour glowing like an ember within the constellation of Pisces. Fast approaching a favourable opposition in the middle of next month, Mars can be seen doing several remarkable things during September.

On 10 September the planet's apparent eastward motion against the background stars stops as Mars reaches what's known as a stationary point. After this Mars will appear to move west until it reaches its next stationary point in mid-November. In reality, Mars hasn't changed direction at all, the effect is simply a consequence of Earth's own orbital motion relative to that of Mars.

The size of Mars increases dramatically this month too. On 1 September a telescope shows the planet to have an apparent size of 18 arcseconds. By the time 30 September has come around, Mars will have grown to appear 22 arcseconds across; a 22% increase in size. The planet's increase in brightness is just as dramatic, Mars brightening from mag. –1.8 on 1 September to mag. –2.5 by the month's end. Mid-month, Mars overtakes Jupiter in the brightness stakes to become the second brightest planet in the sky after Venus.

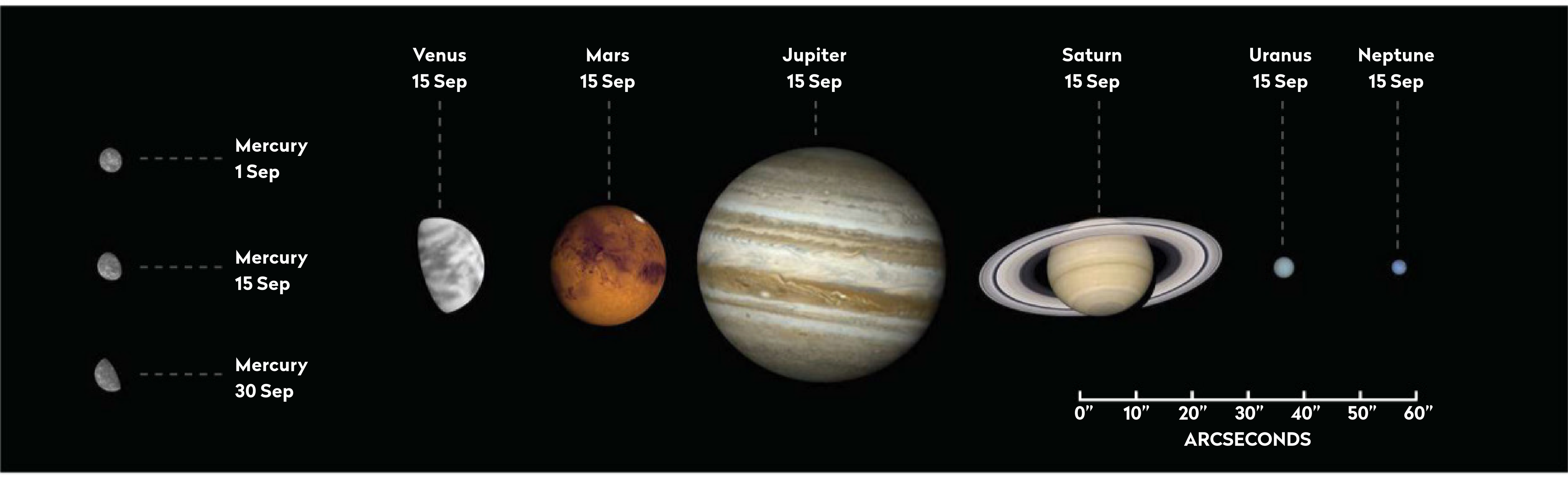
On the evening of 5 September Mars is joined by an 87%-lit waning gibbous Moon. At 23:00 BST (22:00 UT) on 5 September both objects appear 3.2˚ apart, measured from the centre of the Moon's disc. Over the remainder of the night and into the morning of 6 September, the separation continues to get smaller. It reaches a minimum value of half a degree around 06:30 BST (05:30 UT) under daylight conditions. With Mars being so bright at this time, it should be easy to follow the pair with binoculars or a telescope despite the Sun being up.

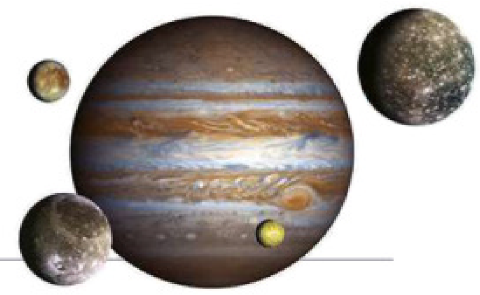

▲ On 10 September, Mars will reach a stationary point

PETE LAWRENCE X 3

The planets in September

The phase and relative sizes of the planets this month. Each planet is shown with south at the top, to show its orientation through a telescope





Venus

Best time to see:
14 September, from
04:00 BST (03:00 UT)
Altitude: 10°
Location: Cancer
Direction: East

Venus is a morning planet and well positioned all month, rising four hours before the Sun. Its phase and size changes dramatically when viewed through a scope in September. On the 1st, shining at mag. –4.1, Venus presents a 19 arcsecond disc, 59%-lit. By the month's end, having dimmed to mag. –4.0, Venus presents a 15 arcsecond disc, 71%-lit.

The 14th is the best time to see the planet visually, as this is when Venus and a slender crescent Moon sit either side of the Beehive Cluster.

Jupiter

Best time to see: 1 September, 21:30 BST (20:30 UT)
Altitude: 14°
Location: Sagittarius
Direction: South

Jupiter is an evening object, reaching its highest position as darkness begins to set in at the month's start. It remains low and is joined by Saturn to the east. On the 1st Jupiter shines at mag. –2.4, dropping to mag. –2.2 by the month's end. A gibbous Moon sits near to Jupiter and Saturn on the evenings of the 24th and 25th.

Saturn

Best time to see: 1 August, 00:30 BST (23:30 UT)
Altitude: 16°
Location: Sagittarius
Direction: South

Saturn appears east of Jupiter, the pair being 7.4° apart on the 30th. It appears low from the UK, only managing to attain an altitude of 16° when due south. Saturn fades this month, from mag. +0.6 on the 1st to +0.8 on the 30th. Through an eyepiece, its rings remain well presented, the northern pole tilted towards Earth by nearly 23°. A waxing gibbous Moon sits 3.2° south on the evening of the 25th.

Uranus

Best time to see: 30 September, 03:00 BST (04:00 UT)
Altitude: 51°
Location: Aries
Direction: South

Uranus is well positioned this month, located in the southern part of Aries and not too far from Mars. It shines at mag. +5.7, making it theoretically visible to the naked eye from a dark-sky site. One problem with this is identifying where Uranus is as this area of sky is bereft of any easy to use navigational patterns. Binoculars are a sure way to see it, as is the use of a scope. Even a small aperture should reveal its green hue.

Neptune

Best time to see: 11 September, 01:10 BST (00:10 UT)
Altitude: 32°
Location: Aquarius
Direction: South

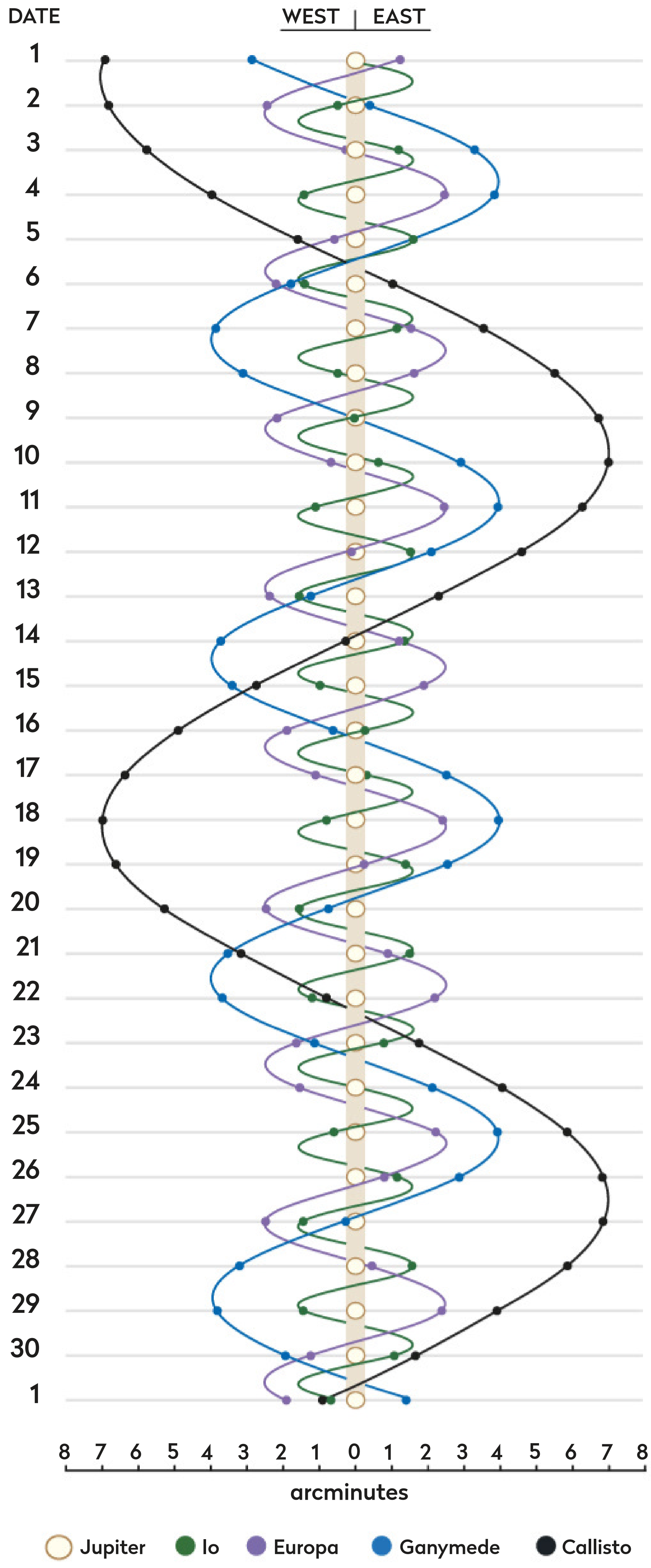
Neptune reaches opposition on the 11th when it can be seen in darkness all night long, shining at mag. +7.8, 2.1° east-northeast of mag. +4.2 Phi (φ) Aquarii. Opposition makes little difference to distant Neptune's appearance in a scope, in contrast to a closer body such as Mars. Being below the threshold of naked-eye visibility, you'll need at least a pair of binoculars to spot it. A scope will reveal the planet's blue-coloured disc.

NOT VISIBLE THIS MONTH:

Mercury

JUPITER'S MOONS: SEP

Using a small scope you can spot Jupiter's biggest moons. Their positions change dramatically during the month, as shown on the diagram. The line by each date represents 01:00 BST (00:00 UT).



THE NIGHT SKY – SEPTEMBER

Explore the celestial sphere with our Northern Hemisphere all-sky chart

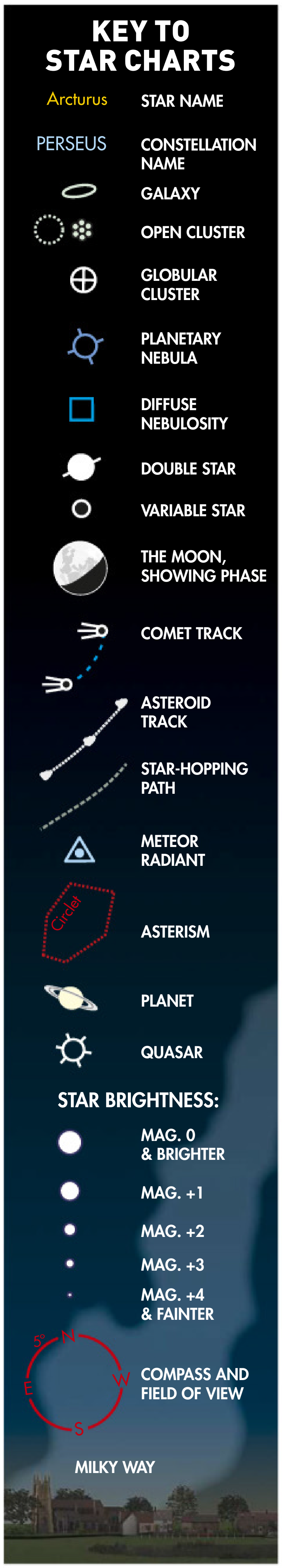


CHART: PETE LAWRENCE

When to use this chart

1 September at 01:00 BST
15 September at 00:00 BST
30 September at 23:00 BST

On other dates, stars will be in slightly different positions because of Earth's orbital motion. Stars that cross the sky will set in the west four minutes earlier each night.

How to use this chart

1. Hold the chart so the direction you're facing is at the bottom.
2. The lower half of the chart shows the sky ahead of you.
3. The centre of the chart is the point directly over your head.

Sunrise/sunset in September*

Date	Sunrise	Sunset
1 Sep 2020	06:20 BST	19:59 BST
11 Sep 2020	06:37 BST	19:35 BST
21 Sep 2020	06:55 BST	19:10 BST
01 Oct 2020	07:12 BST	18:46 BST

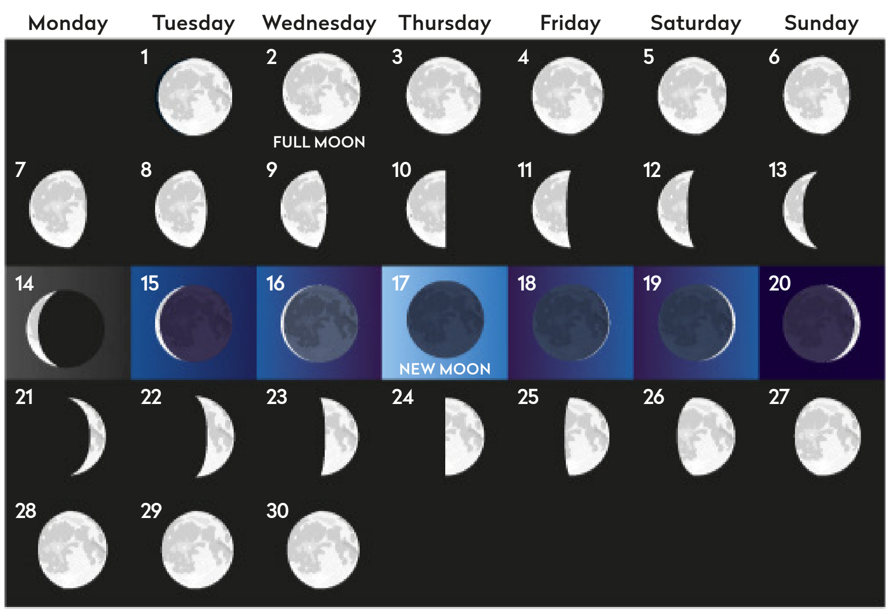
Moonrise in September*

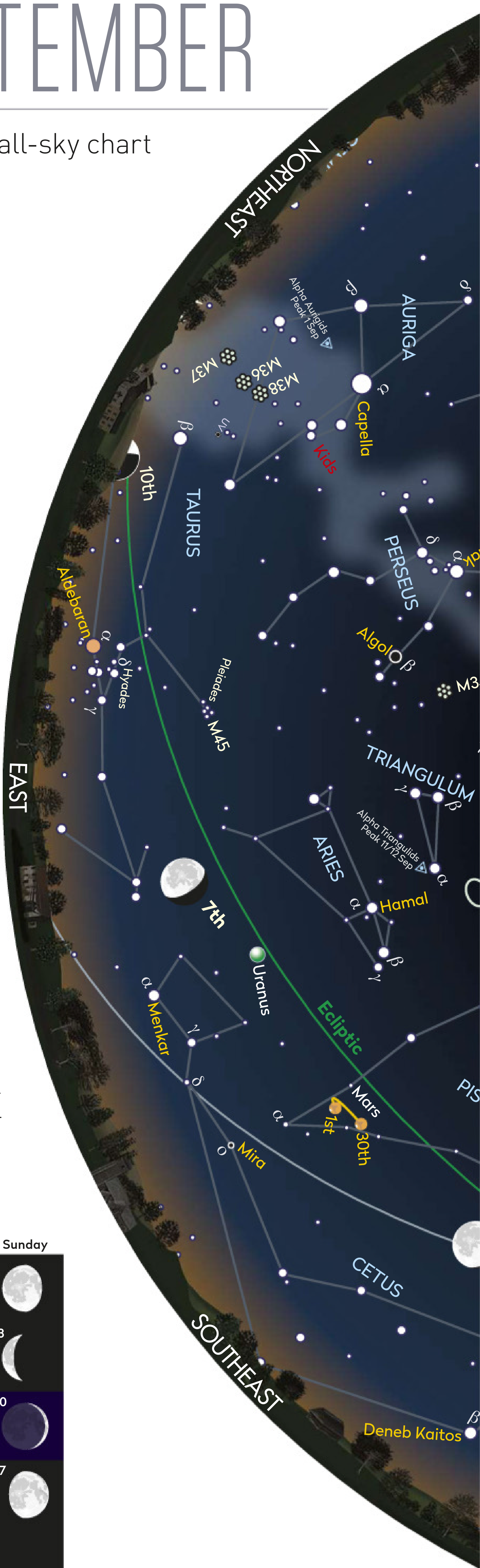
Moonrise times

1 Sep 2020, 20:18 BST	17 Sep 2020, 06:18 BST
5 Sep 2020, 21:16 BST	21 Sep 2020, 12:17 BST
9 Sep 2020, 22:31 BST	25 Sep 2020, 16:57 BST
13 Sep 2020, 00:47 BST	29 Sep 2020, 18:43 BST

*Times correct for the centre of the UK

Lunar phases in September

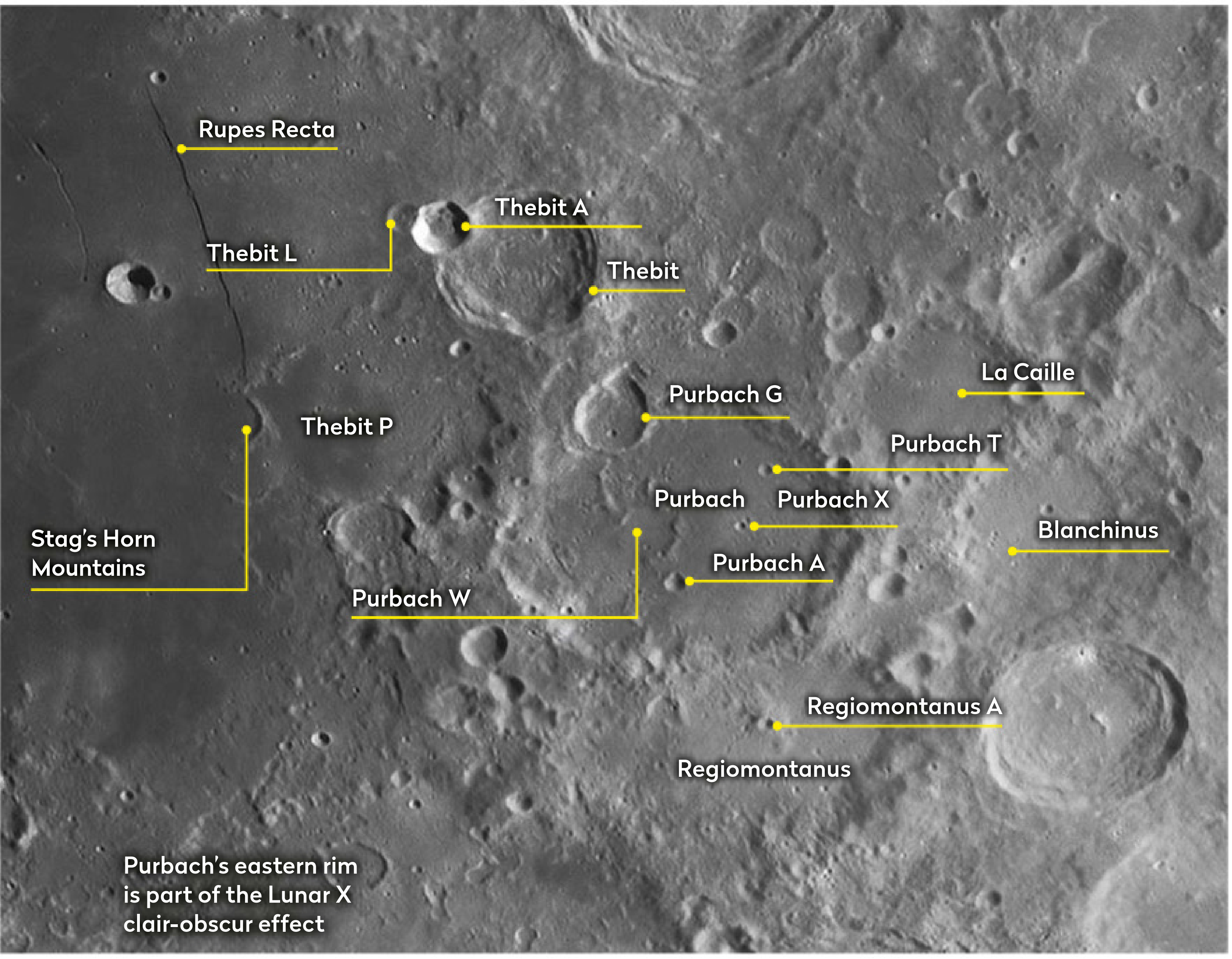




MORE ONLINE

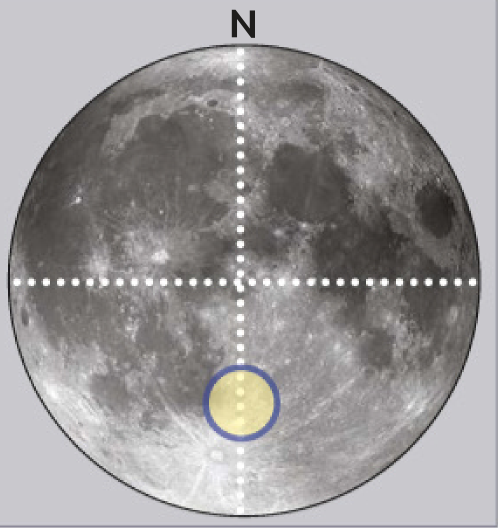
Paul and Pete's night-sky highlights

Southern Hemisphere sky guide



Purbach

Type: Crater
Size: 118km
Longitude/latitude:
2.0˚ W, 25.5˚ S
Age: Older than 3.92 billion years
Best time to see: Six days after full Moon (9-10 September), and first quarter (24-25 September)
Minimum equipment:
50mm refractor



Purbach is a large and quite ancient crater. If you're a fan of the shadow and light play which produces clair-obscur effects, you may be familiar with at least part of Purbach as its eastern rim forms part of the Lunar X. The other craters involved are 68km **La Caille** to the northeast and 68km **Blanchinus** to the east.

Purbach is a fairly battered crater, although its eroded rim is largely intact, appearing best defined to the east. The crater's floor sits at a depth of 3km and is largely flat in appearance apart from a series of flooded ghost craters in the northwest quadrant. The best defined of these is 20km **Purbach W**, slightly west of the centre of Purbach. To the south of Purbach W is **Purbach A**, an 8km craterlet with another small craterlet embedded in its northern rim.

If you're able to see Purbach A, try for the trickier **Purbach T** close to the northeast rim. At 5km across this is a good test for a 100mm scope. Mid-way between T and A sits tiny **Purbach X**. At just 4km across at least a 200mm scope is needed to see it. A much easier member of the Purbach family interrupts the main crater's rim to the northwest, another flat-floored feature, identified as **Purbach G**. Purbach's western rim is interesting because there appears to be another rim arc that extends north, passing to the west of Purbach G. Inside Purbach, this gives the impression of a double rim. As ever, the appearance of these features is enhanced when lighting is oblique, a situation which occurs when the Sun is low in Purbach's sky.

South of Purbach lies ancient **Regiomontanus**. At 126km across this crater is similar in size to Purbach, but it's far less distinct. Its rim is eroded and irregular with an oval shape, 126km at the widest point but only 110km at the narrowest. A ridge of material aligned north-northwest to south-southeast runs from its northern edge, where it connects to Purbach, into the centre of the crater. A tiny 6km craterlet, **Regiomontanus A** sits close to the centre of the main crater, on the ridge.

To the northwest of Purbach G lies the well-defined form of 58km **Thebit**. Fairly unremarkable at first glance, the circular rim of Thebit appears to have two similar-sized scalloped out regions to the south. The northwest portion of the rim is interrupted by 20km **Thebit A**. Like Russian dolls, look at Thebit A and its northwest rim appears interrupted by 12km **Thebit L**.

To the southwest of Thebit and northwest of Purbach sits the completely flooded crater **Thebit P**. Despite having a diameter of 78km, this is the most eroded feature yet, its outline being very difficult to discern at all. The western edge is marked by an arc-like ridge unofficially called the **Stag's Horn Mountains**. The arc is part of another clair-obscur effect called the Cutlass. The effect is completed by the presence of **Rupes Recta**, the Straight Wall, which appears to stretch from the top of the arc for a distance of 120km to the north-northwest.

COMETS AND ASTEROIDS

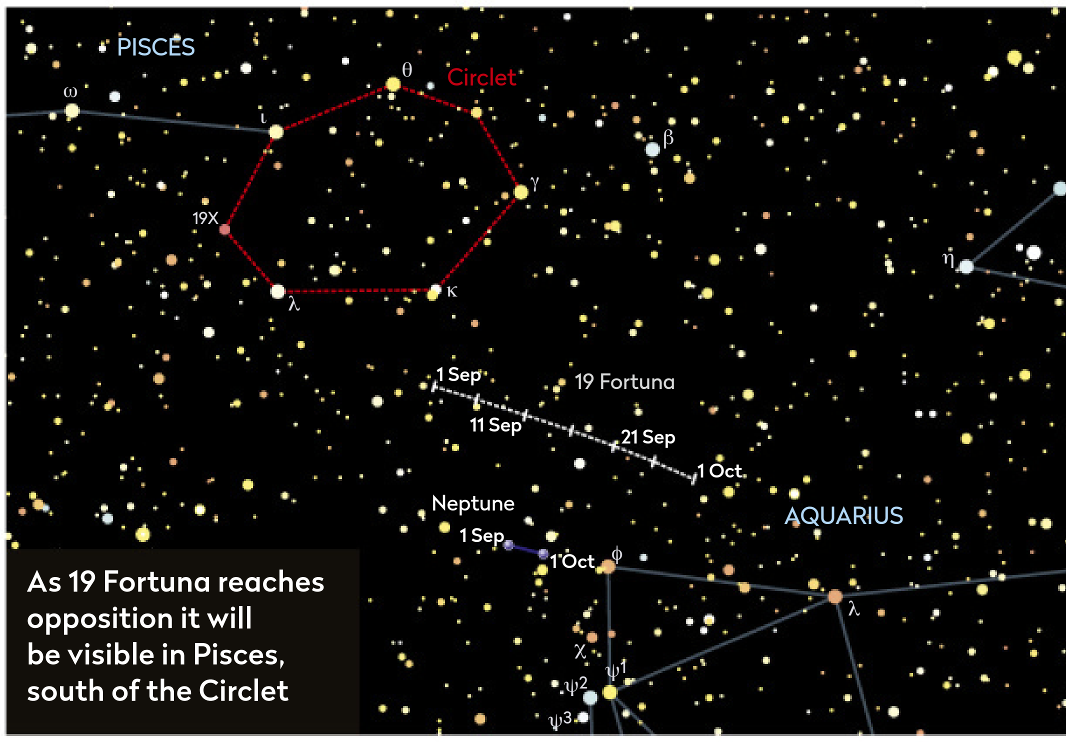
Asteroid 19 Fortuna reaches opposition in Pisces on 11 September

Minor planet 19 Fortuna reaches opposition on 11 September in the constellation of Pisces, south of the faint asterism of the Circlet. Shining at mag. +9.2 it should be a relatively easy target for a small scope. It tracks southwest throughout September, pushing Fortuna into the neighbouring constellation of Aquarius by the month's end. Fortuna's track location also keeps it relatively close to the Solar System's outermost planet Neptune throughout the month. Medium wide images of the area taken several days apart should reveal the motion of both bodies. Neptune will appear brighter than Fortuna at mag. +7.9.

19 Fortuna is a large main belt asteroid, with a diameter of 225km. It's quite dark in appearance with an albedo – how much light it reflects – of just 3.7%. Its peak brightness at favourable oppositions can reach mag. +8.9, but at its dimmest it sinks to mag. +13.0. As a carbonaceous asteroid, it falls into an uncommon class known as a G-type. Approximately 5% of asteroids are G-type including the largest, dwarf planet Ceres.

Fortuna's orbit takes it out as far as 2.8 AU from the Sun and in as close as 2.1 AU. It takes 3.81 years to complete each orbit, spinning on its axis once every 7.4 hours. It's had close encounters with other bodies, its orbit being perturbed by the 76km asteroid 135 Hertha. This allowed the mass of Fortuna to be derived to be 1.08 x 10^{19}kg, a value which has more recently been refined to 1.27 x 10^{19}kg. In 2012 Fortuna passed within 6.5 million km of the small 25km asteroid 687 Tinette, with no significant consequence.

In 1993 the Hubble Space Telescope was able to determine that Fortuna was virtually spherical. Incredibly, at the time the asteroid presented an apparent size of just 0.2 arcseconds.



As 19 Fortuna reaches opposition it will be visible in Pisces, south of the Circlet

STAR OF THE MONTH

Seeing red in the Great Square of Pegasus

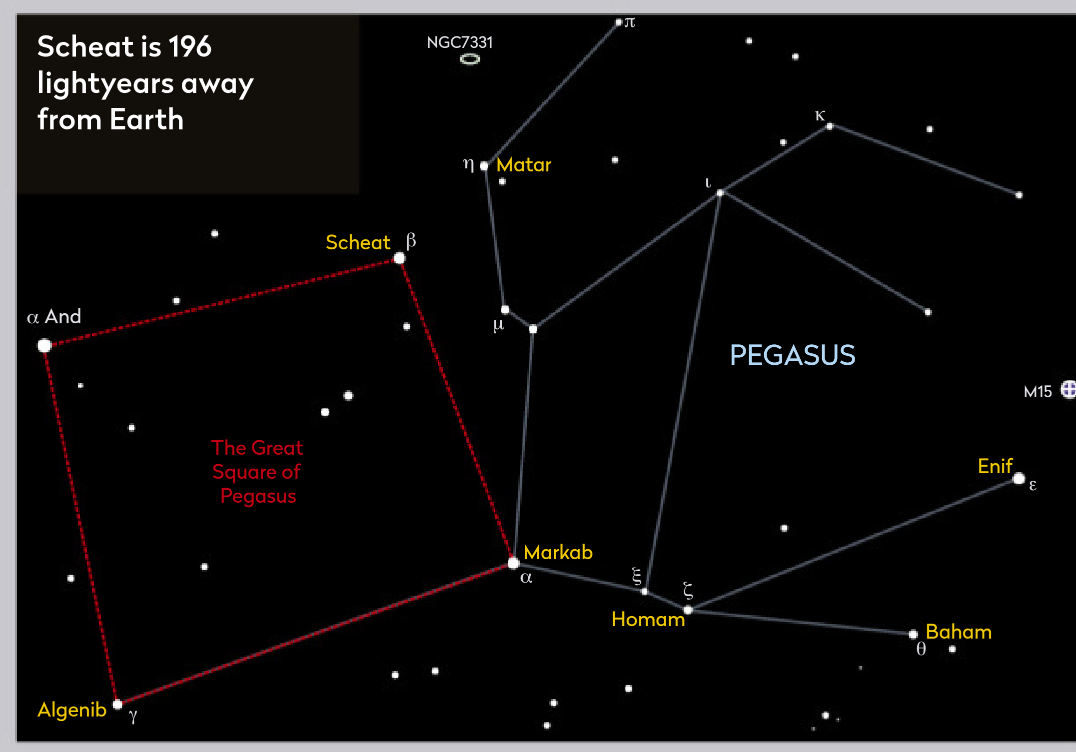
The Great Square of Pegasus is a cornerstone of autumn skies. It's a large pattern, not especially bright, formed from three stars in Pegasus and one from Andromeda. The star Scheat (Beta (β) Pegasi) marks the square's northwest corner.

Scheat's colour makes it stand out from the other corner stars, which are all hot and blue. Scheat is a red star with a spectral classification of M2.5II-IIIe. M2.5 indicates its spectral class, M-stars being cool and orange-red in colour. The II-III indicates that it lies between a bright giant (II) and a normal giant (III). The 'e' tells us emission lines are present in its spectrum.

Scheat is 196 lightyears away and at that distance, in order to appear as bright as it does in the night sky, it must radiate in the visual part of the spectrum with a luminosity equal to 340 Suns. However, being a cool red star, much of Scheat's output is in the infrared part of the spectrum and when this is factored in, the star is around 1,500 times more luminous than our own Sun.

It's known to be 95 times larger than the Sun. The apparent diameter of the star is 0.015 arcseconds which, at 196 lightyears distant, gives us its size. Like many red giant stars, Scheat exhibits variability. This is due to intrinsic processes within the star. Its brightness varies from mag. +2.3 to +2.7 over 43.3 days, but there is irregular variation here too. Scheat is a class of star known as a semi-regular variable.

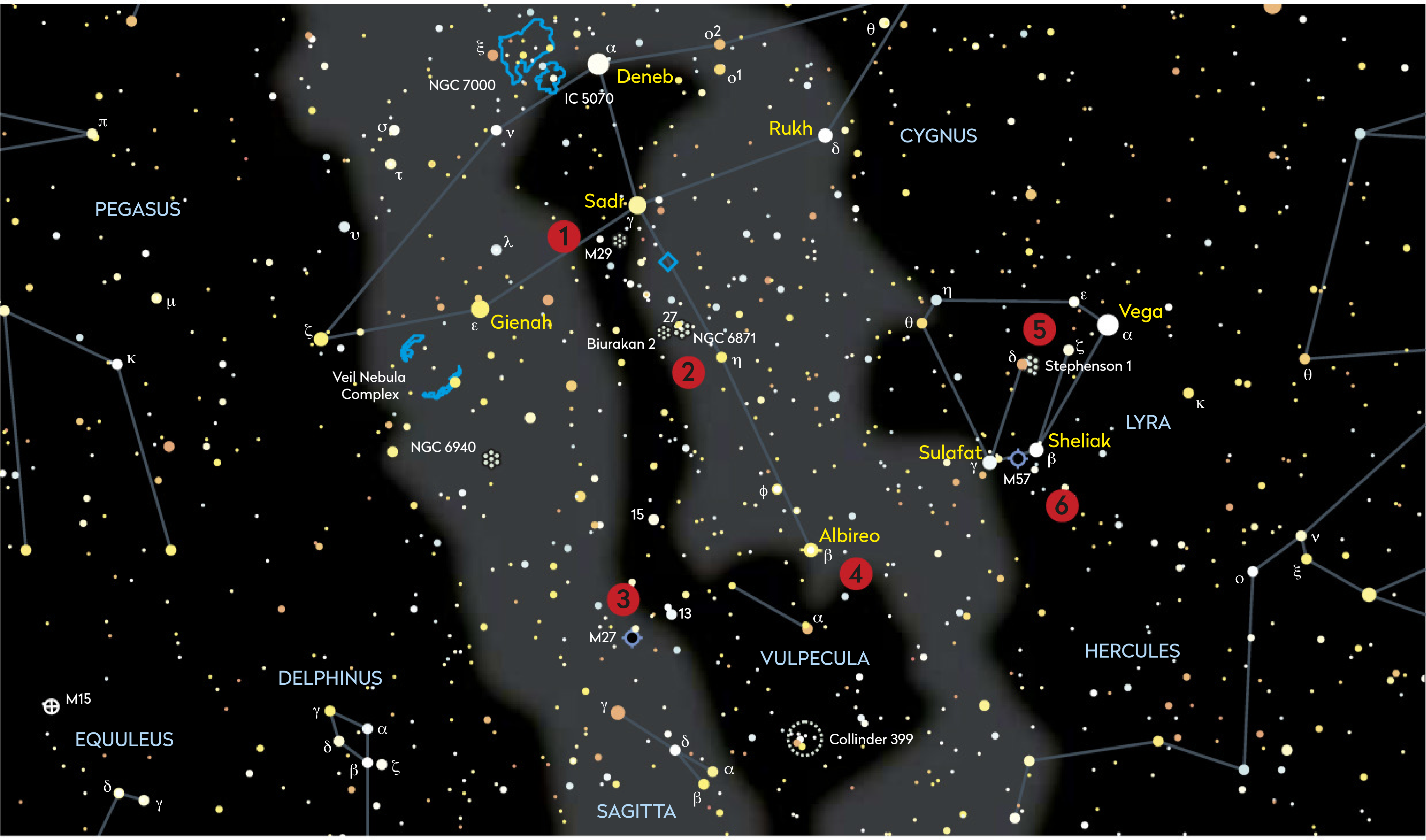
As the beta star of Pegasus, it's fitting that Scheat is actually the second brightest star in the constellation. However, this is not after Markab (Alpha (α) Pegasi), but rather after Enif (Epsilon (ε) Pegasi), which is slightly brighter. The name Scheat derives from the Arabic word for 'shin'.



Scheat is 196 lightyears away from Earth

BINOCULAR TOUR With Steve Tonkin

This month's wide-field wonders include the double star Albireo and the Ring Nebula



1. M29

15x 70 Although you can easily see this open cluster in small binoculars, this little object (7 arcminutes diameter) really lends itself to more magnification. Put Sadr (Gamma (γ) Cygni) at the north of the field of view and the cluster will be near the centre. Depending on your sky conditions, you should see up to 20 stars, including two arcs of brighter ones that form a 'power station cooling tower' shape. ☐ **SEEN IT**

2. NGC 6871

10x 50 Our next open cluster is brighter and much larger, and contains a lovely variety of star colours. The brightest of these, orange 27 Cygni, is a foreground star however. At 5,100 lightyears, the young blue and white stars of the cluster are more than 60 times as distant. Notice how the brighter stars in the cluster seem to form pairs. The brightest blue star, HIP 99002, is the brightest Wolf-Rayet star visible from the UK. ☐ **SEEN IT**

3. M27

10x 50 From Gamma (γ) Sagittae, scan a little more than 3° in the direction of 15 Vulpeculae where you will find a tiny glowing cloud. This is the Dumbbell Nebula. Initially it will appear rectangular but, with patience and averted vision, you should make out the slight narrowing in the middle that gives it its common name. It is 1,360 lightyears away with a diameter of about two lightyears. ☐ **SEEN IT**

4. Albireo

10x 50 The meaning of the name Albireo (Beta (β) Cygni) is lost in time, but we know it as the beautiful double star that marks the Swan's eye. The components are separated by 34 arcseconds, so are a good test of 10x magnification: you will need to have perfect focus and steady binoculars. Once you have split it, notice the beautiful colour contrast between the golden (mag. +3.1) primary and the azure (mag. +5.0) secondary. ☐ **SEEN IT**

5. Stephenson 1

10x 50 Stephenson 1 is a cluster that deserves to be better known. Delta (δ) Lyrae is a very wide (10 arcminutes) double star with a colour contrast that easily outdoes Albireo. This not a true double: the difference in distance is about 200 lightyears. Our cluster lies immediately southwest of the pair and initially appears as a granular patch of sky, but patience and averted vision will help you to resolve the brighter stars. ☐ **SEEN IT**

6. M57

15x 70 Our second planetary nebula is a challenge. The mag. +9.5 Ring Nebula, M57, lies almost mid-way between Sheliak (Beta (β) Lyrae) and Sulafat (Gamma (γ) Lyrae), making it easy to locate, but it's less easy to identify. You are seeking what looks like a faint defocused star, but don't expect to see the hole in the ring. ☐ **SEEN IT**

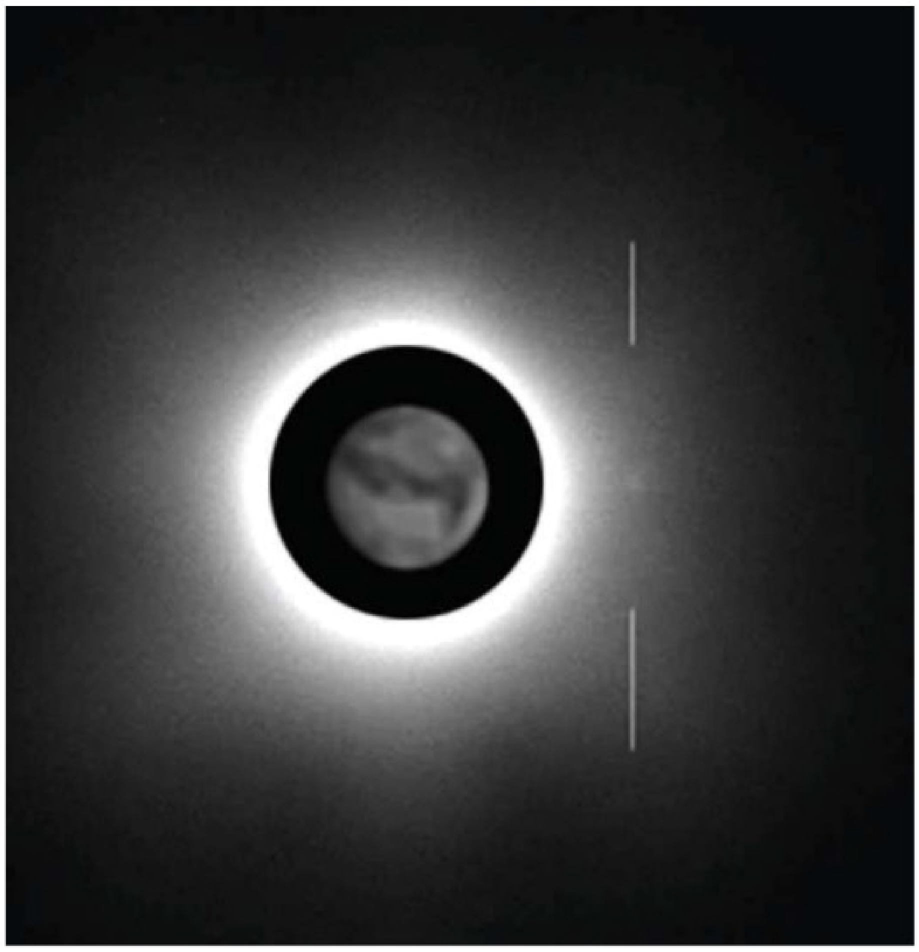
☑ Tick the box when you've seen each one

PETE LAWRENCE X 3

THE SKY GUIDE CHALLENGE

Can you observe Phobos and Deimos, the two small moons of Mars?

▲ **Use an occulting bar, a strip of aluminium foil attached at the focal plane of the eyepiece, to help you hide Mars and see its moons**



▲ **Phobos, here caught on camera near opposition, has a closer orbit around the Red Planet than Deimos**

Mars has two tiny moons, Phobos and Deimos. This month's challenge is to try and see or image them. And when we say tiny, we aren't joking: the inner moon Phobos measures 27 x 22 x 18km, while Deimos is just 15 x 12 x 11km. They both keep pretty close to the Red Planet as well: Phobos's orbit has a mean radius of 9,376km (2.76 Mars radii) and that of Deimos is 23,463km (6.92 Mars radii). At opposition Mars will appear 22.6 arcseconds across, while Phobos is able to appear 30 arcseconds from the planet's centre and Deimos 77 arcseconds. When Mars is well away from opposition, the moons are too faint and close to the planet to be viable targets, but when it approaches a favourable opposition, the story is somewhat different.

First, let's deal with their brightness; Phobos shines at mag. +10.7, while Deimos is a bit fainter at mag. +11.8. Although these aren't ridiculously low magnitudes, the fact that Mars will be at mag. –2.5 at the end of September creates a hurdle. Two faint dots orbiting such a bright host will make recording them that much harder.

To stand the best chance of seeing or photographing the moons, you'll need an image scale showing the disc of Mars clearly. The moons will be easiest to see when close to an eastern or western elongation, in other words when they appear furthest from the planet. Phobos orbits Mars once every 7 hours 39.2 minutes, while Deimos, being further out, takes longer at 30.3 hours. For Phobos there will be several viable elongations every night, while it may take several nights to get lucky with Deimos. There are a number of programs and apps which can be used to show you where the Moons are relative to the Red Planet; the free WinJUPOS software is a good example for Windows-based computers.

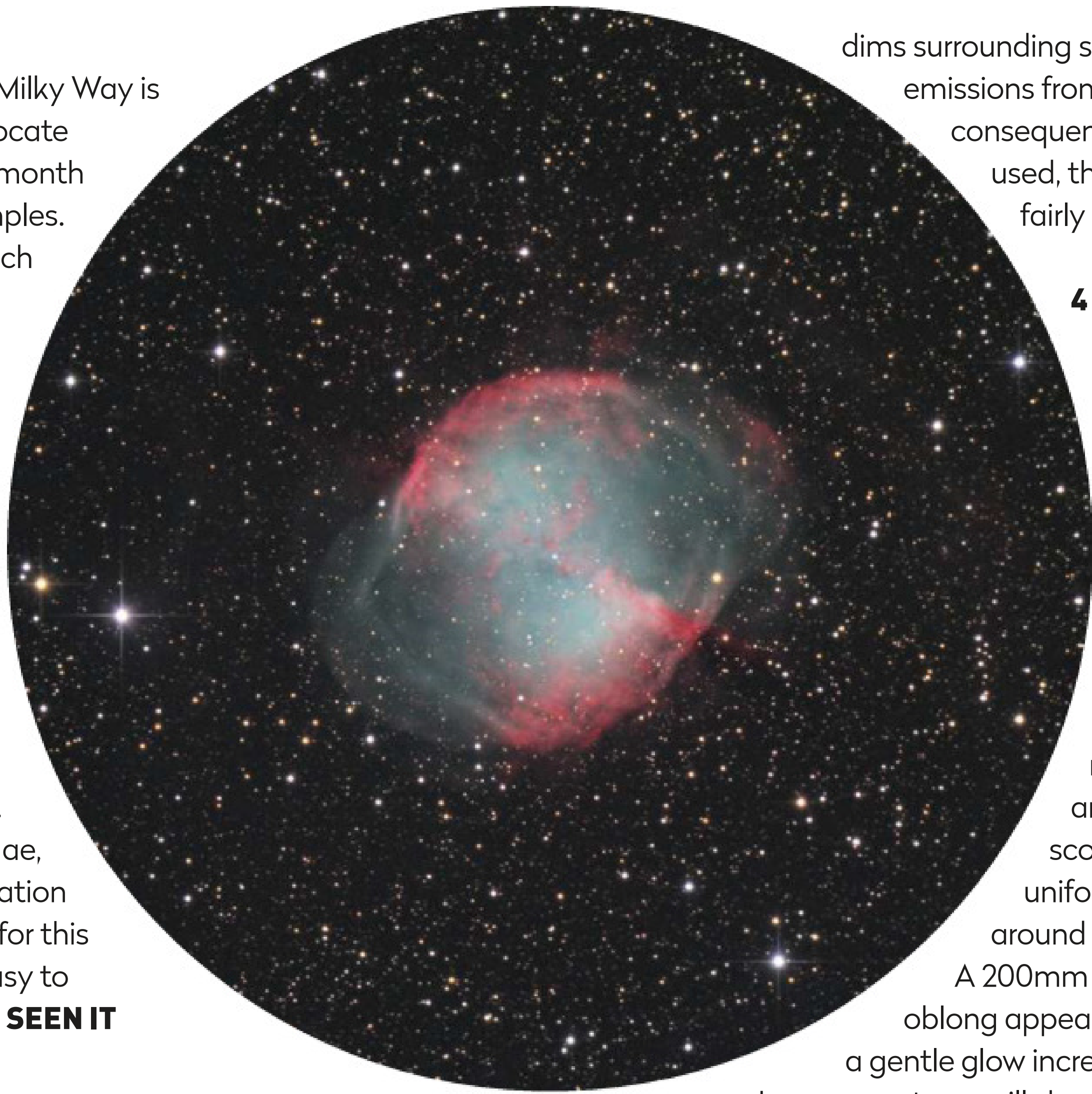
The moons will be easiest to see when close to an eastern or western elongation, as they appear furthest from Mars

Visually there is a way to help you see both moons when close to an elongation. Attach a thin strip of paper or aluminium foil to the focal plane of your chosen eyepiece to create an optical device known as an occulting bar (pictured above, left). This will give you something to hide Mars behind. The focal plane of an eyepiece is normally marked by a ring called the field stop; the bar should be attached to this. In use, simply position the bar north-south, hide Mars behind it and if they're there, the moons should be a lot easier to spot.

If you intend to use a camera, Mars will need to be overexposed. The trick is to overexpose the planet while trying to keep the level of overexposure low enough to stop it spreading over the regions where the moons will be located.

DEEP-SKY TOUR

We search for planetary nebulae targets, including the Dumbbell Nebula, M27



▲ **Grand finale: the Dumbbell Nebula, M27, is large and bright**

1 NGC 6891

The plane of the Milky Way is a great place to locate planetary nebulae, and this month we're hunting down six examples. We start with NGC 6891, which sits on the Delphinus-Aquila border. It lies 2.5° south of the star Rho (ρ) Aquilae. As an aside, despite being an Aquila star, Rho technically sits within Delphinus. NGC 6891 shines with an integrated magnitude of +10.5 and is around one-third of an arcminute across. A 150mm scope will show it, although it's easy to mistake as a star. As ever with planetary nebulae, carefully increased magnification works best. The central star for this object is mag. +12.4 and is easy to see with a 250mm scope. ☐ **SEEN IT**

2 IC 4997

Return to Rho Aquilae and look 2.1° northeast to find IC 4997. Located in the southwest corner of Sagitta, this planetary is a visual test because it's faint at mag. +12.0, and small at just 2 arcseconds across. To most people it will appear like a dim star. Using an OIII filter will help it stand out. If you have a large scope, you'll need a high magnification to see any structure. The nebula has a bi-lobe appearance, two glowing 'ears' either side of a 14th magnitude central star. It's believed to be a young planetary, with some estimates saying it formed just 700 years ago. ☐ **SEEN IT**

3 NGC 6879

Return again to Rho Aquilae and head 1.9° north-northwest to locate NGC 6879. This planetary doesn't show a great deal of detail through amateur scopes, the challenge is just being able to find it. It shines with an integrated magnitude of +12.5 and appears for the most part quite stellar. Being just a few arcseconds across its propensity to masquerade as a star, combined with its location against a rich background star field, makes identification tricky. If you have an OIII filter this is where this essential tool of the planetary nebula hunter comes into its own. The filter dims surrounding stars while allowing many emissions from the nebula through. As a consequence, when an OIII filter is used, the nebula should become fairly obvious. ☐ **SEEN IT**

4 NGC 6905

For our next target we return to Delphinus. Nestled in the northwest corner of this constellation, 5.2° north-northeast of Rho Aquilae, is planetary nebula NGC 6905, also known as the Blue Flash Nebula. It shines at mag. +11.1 and is nearly 40 arcseconds across. A 150mm scope shows it as a circular, uniform patch of light, best around 100x to 150x magnification. A 200mm instrument shows an almost oblong appearance, while 250mm reveals a gentle glow increasing towards the centre. Larger apertures will show the nebula with a distinct blue colour and a mottled appearance. NGC 6905 sits within a triangle of mag. +10.6, +11.5 and +11.6 stars. The nebula's central star shines at mag. +14.2. ☐ **SEEN IT**

5 NGC 6886

We hop over the border back into Sagitta for planetary nebula NGC 6886. This can be found 4.8° north of Rho Aquilae. This nebula shines with an integrated magnitude of +11.4, only a fraction dimmer than NGC 6905, but it's smaller at just 9 arcseconds across, giving it a slightly improved surface brightness. The nebula is probably best identified through the part it plays in forming a small pointed triangle with two other stars of mag. +10.3 and +11.1. The nebula marks the western vertex of this almost-isosceles, east-northeast pointing triangle. A 250mm scope shows little more than a stellar dot here. It takes a 300mm instrument with a magnification of over 400x to begin to show NGC 6886 as a green hued disc. ☐ **SEEN IT**

6 M27

The Dumbbell Nebula, M27, is a superb example of its class. The planetary can be found 3.2° north of Gamma (γ) Sagittae and shines with an integrated magnitude of +7.3. At 8.0 x 5.7 arcminutes in size it's a large object. A 150mm instrument shows M27's characteristic 'apple core' appearance, two bright lobes symmetrically located about the object's centre. Careful examination reveals the lobes to be of unequal brightness, that to the southwest appearing brighter. M27's central star shines at mag. +13.8. ☐ **SEEN IT**

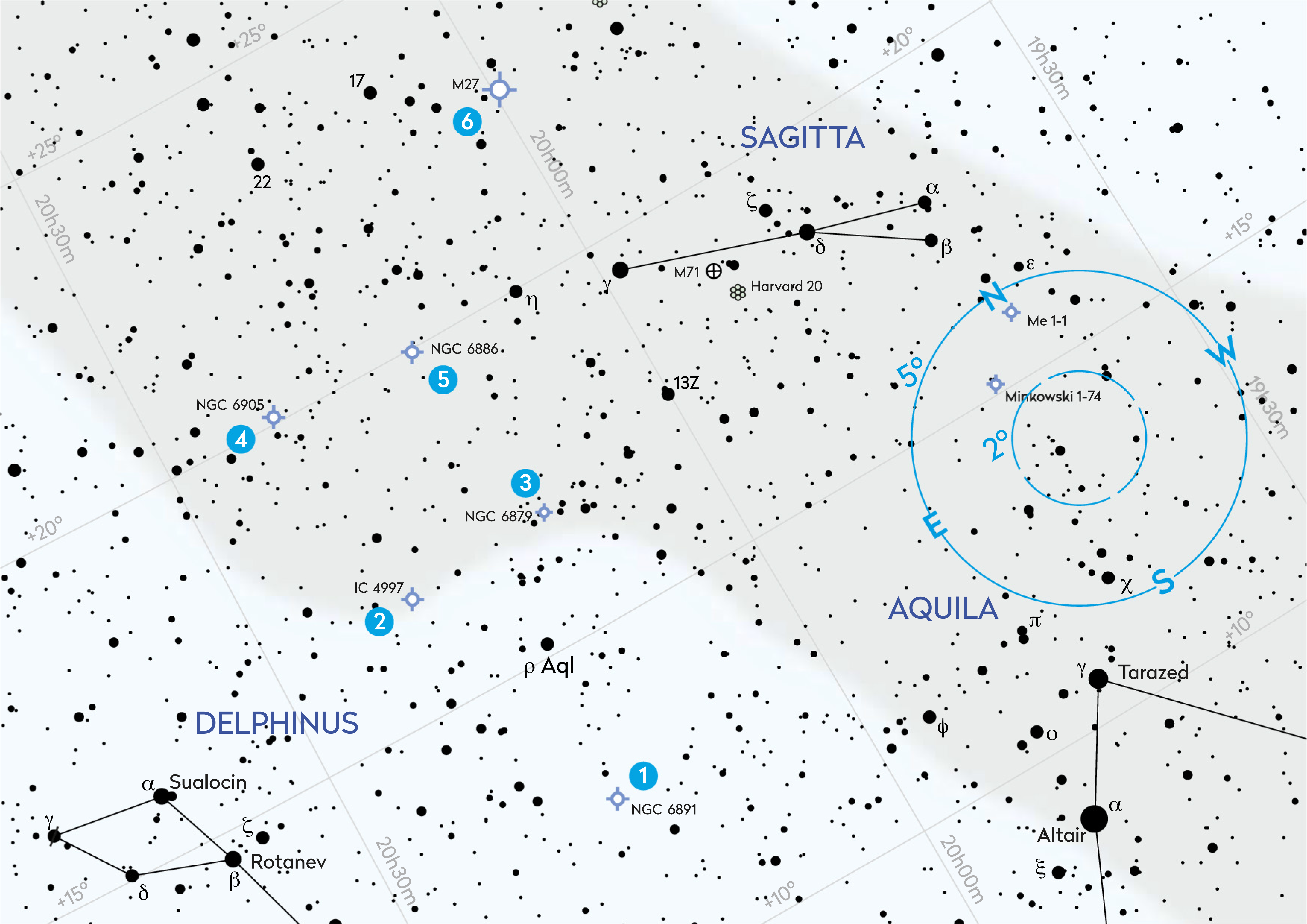
This Deep-Sky Tour has been automated

ASCOM-enabled Go-To mounts can now take you to this month's targets at the touch of a button, with our Deep-Sky Tour file for the EQTOUR app. Find it online.

More **ONLINE**

Print out this chart and take an automated Go-To tour. **See page 5 for instructions.**

JOHANNES SCHEDLER/CCDGUIDE.COM, CHART BY PETE LAWRENCE


SAGITTA
AQUILA
DELPHINUS
M27
6
17
22
NGC 6886
5
NGC 6905
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NGC 6879
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IC 4997
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NGC 6891
1
M71
Harvard 20
13Z
Me 1-1
Minkowski 1-74
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Altair
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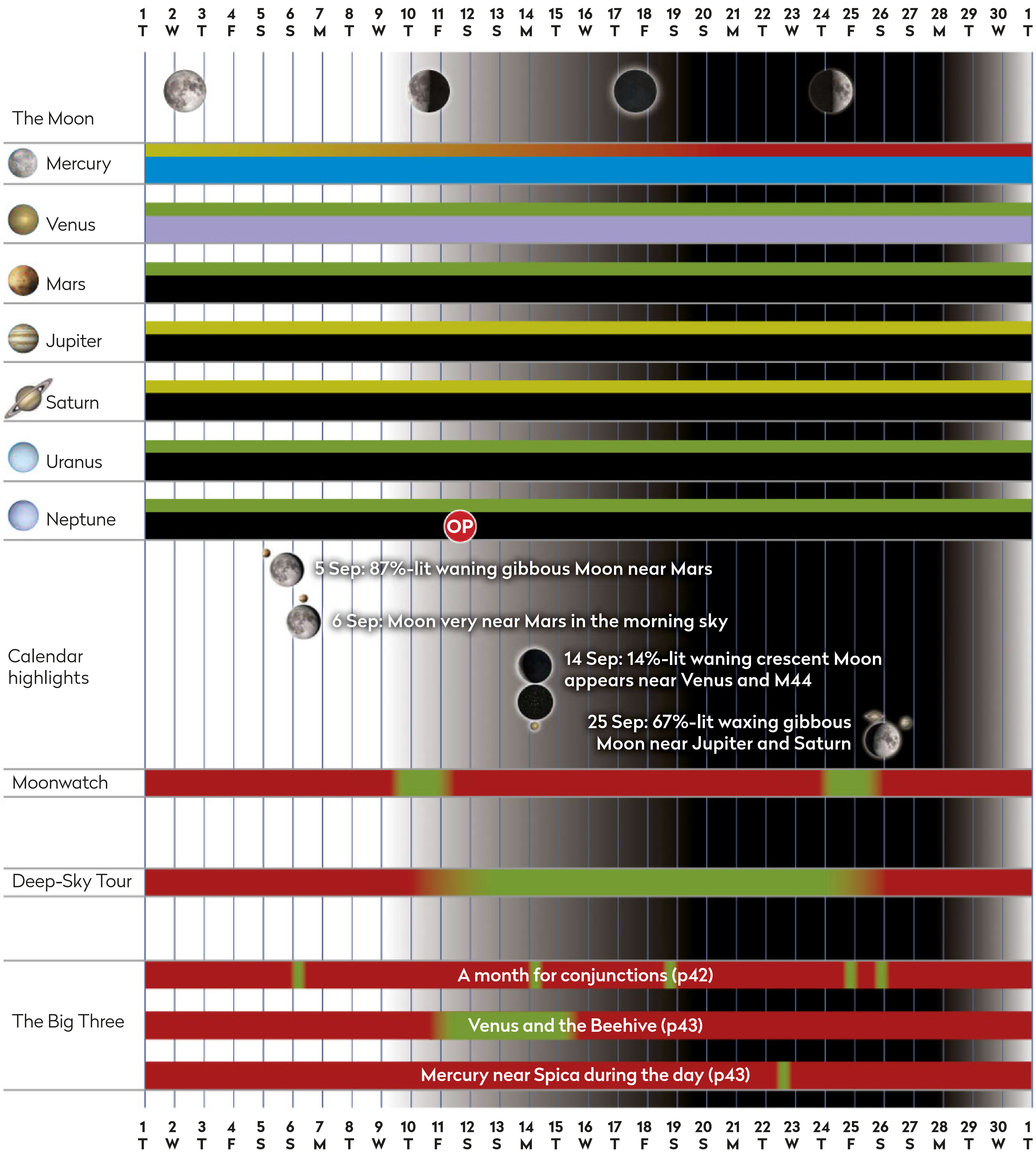
AT A GLANCE How the Sky Guide events will appear in September



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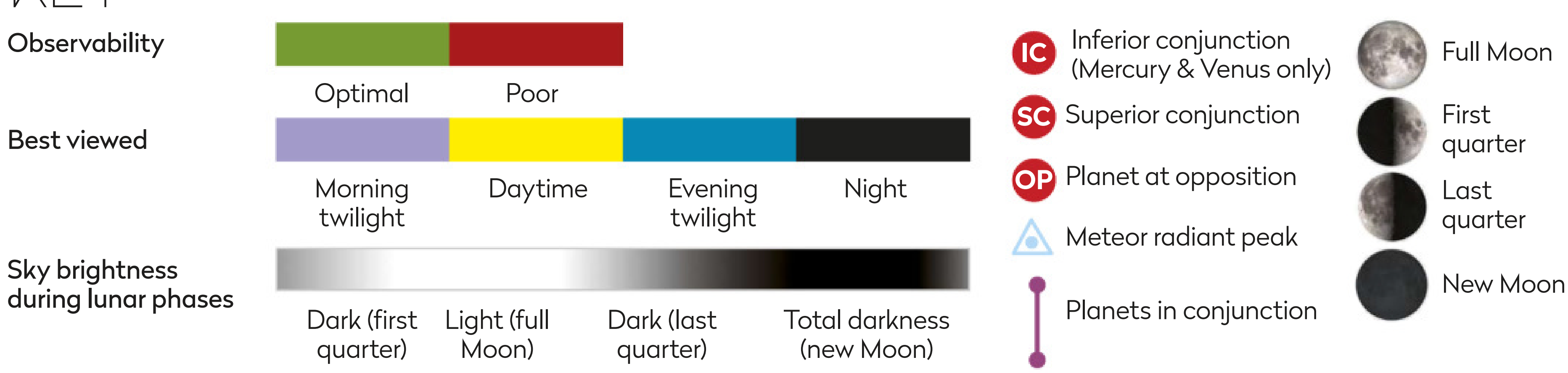


CHART BY PETE LAWRENCE

SPARKLING STARS

A sky safari with binoculars

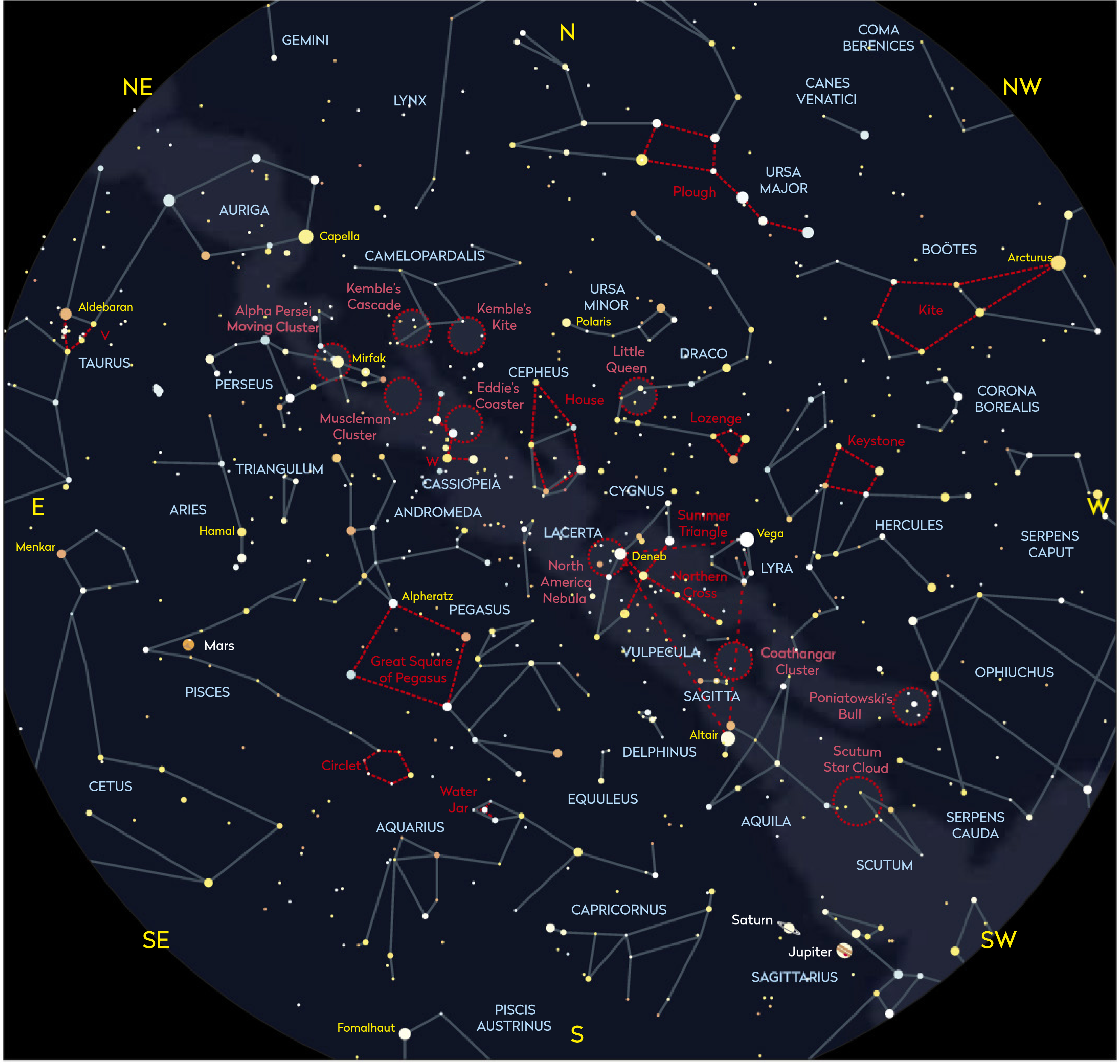
Binoculars are a great way to get into stargazing, and Steve Tonkin's tour designed especially for them will take you to some of the best targets for two eyes this month

Some celestial targets look better with binoculars than anything else

JON HICKS

There's one piece of advice that should be familiar to anyone who is trying to get started in astronomy – buy a pair of binoculars and use them to learn your way around the night sky. But once you have a pair, where do you start? Here, we take you on a trip across the night sky, looking at 10 of the best stellar groups visible in September.

We've chosen several large targets that are arguably better in binoculars than anything else – it would be daft to omit these – as well as targets that help you develop useful observing skills, and a couple that push these skills to their limits. There are even several circumpolar objects which will be visible in UK skies throughout the year, so you can continue to observe them if you wish. We recommend 10x50 binoculars for this, but all of the objects are visible with a smaller pair, so dust off whatever you have and let's get observing! ►



We get things going with a circumpolar sight that's easy to find. The **Alpha Persei Moving Cluster** extends 4° southeast from Mirphak (Alpha (α) Persei). When you track it down, you should see stars shining with an intense blue-rich whiteness that indicates that they are young stars. In binoculars, they are said to 'sparkle like diamonds on black velvet'. The cluster is said to be 'moving' because all the stars have the same proper motion (their apparent movement on the night sky). The reason we're starting here though is that they're a great place to ensure your binoculars are perfectly focused: focus them until you get the maximum number of visible stars.

With our binoculars in crisp focus, it's time to take a trip over to southerly skies to look at a duo of sights, starting with the spectacular **Scutum Star Cloud**. Located in the southern sky, it's so easy to find that it has been mistaken for a real cloud on a clear night. Note how there seem to be ripples of stars; these are formed by indistinct dark nebulae that weave through it. The richest part is the densest known open cluster, M11, the Wild Duck Cluster. Were it not so rich, it would be very difficult to distinguish from the background star cloud, which itself forms one of the most densely packed regions of the Milky Way.

▲ Use this chart to help you find our tour's targets. It shows the sky at midnight BST (23:00 UT) on 1 September

CHART BY PETE LAWRENCE, STEPHEN TONKIN X 3

About 15° northwest of the Scutum Star Cloud we find another ideal object for binoculars. **Poniatowski's Bull** has a diameter of about 4° and so fits comfortably in the field of view of 10x50 binoculars. The brightest stars include 66, 67, 68, 70 and 73 Ophiuchi, which form a V-shape similar to the Hyades cluster in Taurus, hence its common name.

Start star-hopping

By now you should be getting your eye in, so we'll leave the southern skies and travel up to Vulpecula and do our first star-hop. Star-hopping is a way of finding a

TOP 5
BINO TIPS

Choose the right location to observe from

Binoculars are so portable that you should easily be able to choose somewhere that is shielded from direct light and gives you an unobstructed view of the regions of sky that you want to observe. Ideally, it will be out of the wind: even a light breeze can be chilly after a few hours. Put up a wind-break if you need to, as it will be worth the effort. If you are observing alone, give some consideration to personal safety; if you are worried about unwelcome visitors, you won't enjoy your observing session and you'll get spooked by any unfamiliar noises.

Sit back and relax: a reclining chair will improve your observing session

Make sure you're comfortable

Astronomical objects are clearer when they are higher in the sky, and the most comfortable way to observe high elevation objects is to recline. A garden recliner with support for your lower legs can be extremely comfortable. It can act as a windbreak for your back, while keeping your feet off the ground, and it provides a useful 'rack' or 'hanger' for your binocular case, charts, notebook, or a flask with a hot drink (keep this away from your optics!). If you dehydrate, your body will reduce circulation to your extremities, so drinking plenty of fluids will also help you to keep warm.

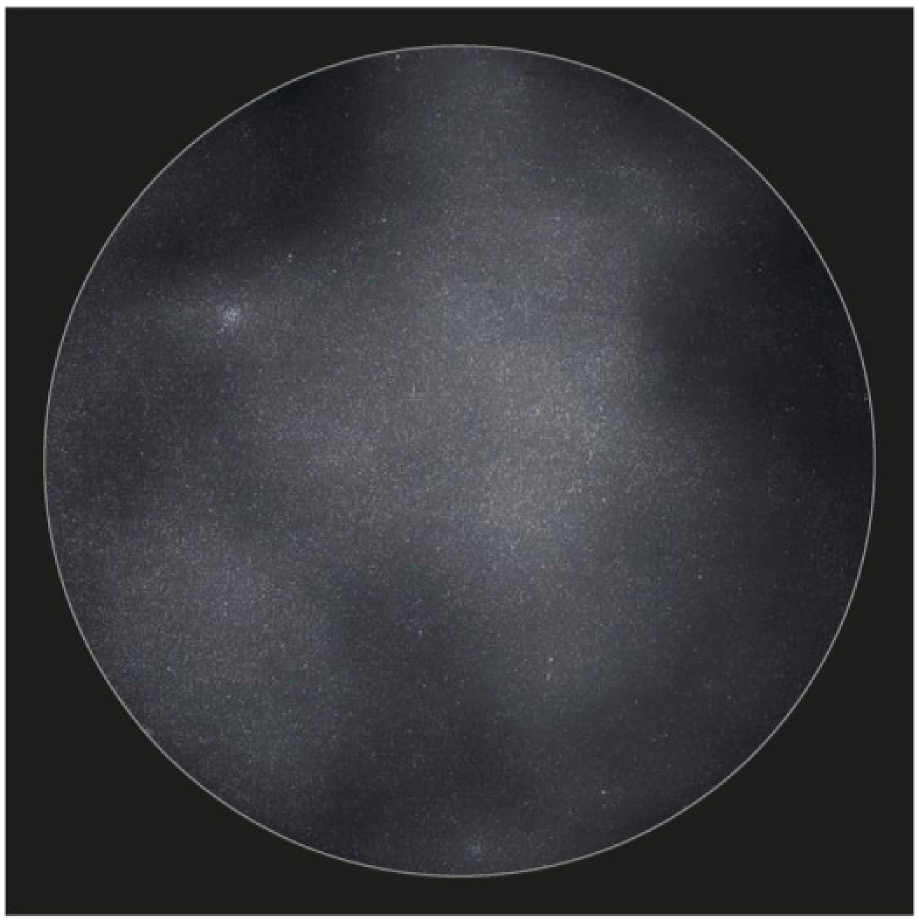
target by navigating from a bright, easy-to-find object to locate less obvious ones nearby. Start at Anser (Alpha (α) Vulpeculae) and navigate 5° (about one field of view of 10x50 binoculars) south, where you'll find **The Coathanger** – a popular star-party piece, because it looks like an everyday object. Even 20mm binoculars will reveal the 10 brightest stars that give this asterism its name. Its formal designation is Collinder 399, but it's also known as Al-Sufi's Cluster after the Persian astronomer Abd al-Rahman al-Sufi who first recorded it back in the 10th century, or Brocchi's Cluster after the astronomer who used it to determine the limiting magnitude of his telescopes.

Steve Tonkin is a binocular observer. Find his tour of the best sights for both eyes on page 50

For our next batch of targets, we'll need to take a slightly larger trip across the sky, requiring a double star-hop to find our next target. Imagine a line from Navi (Gamma (γ) Cassiopeiae) through Ruchbah (Delta (δ) Cassiopeiae) and extend it for 7.5° (about one and a half fields of view). Look for a very close pair of small open clusters, the Perseus Double Cluster (you might be able to see them with your naked eye as a single fuzzy blob). But this isn't our final destination: from the side nearest Cassiopeia there is a 2° curved chain of stars leading northwards to Stock 2, also known as the **Muscleman Cluster**. This gets its name from the stick-man figure made by its brighter stars. He stands with his feet to the east in a bicep-flexing pose, wielding the Double Cluster on a leash (the starry chain that led us here). The connection between the Muscleman and the Double Cluster is purely illusory: the Double Cluster is nearly seven times as far from Earth as the Muscleman.

Kite markers

Our next asterism is **Kemble's Kite**, named for the prolific Canadian binocular observer, Father Lucien Kemble (1922-99), who observed it with 7x35 binoculars. A line from Segin (Epsilon (ε) Cassiopeiae) through Iota (ι) Cassiopeiae leads to Gamma (γ) Camelopardalis, 8° further northeast. Approximately 1.5° west of Gamma (γ) Camelopardalis, you'll find a yellowy-orange star, V805 Cassiopeiae. V805 is the brightest of a 1.5° long



▲ Perhaps it's no surprise that the Scutum Star Cloud – located in the southern sky – can be mistaken for a real cloud. (All the binocular views shown here are north-up)

▲ The Coathanger in the constellation of Vulpecula is a popular binocular target and it's a good one on which to practise the technique known as star-hopping

▸ group of 10 stars (mag.+8.0 and +9.0) that form a diamond kite with a tail that flows southwards towards Perseus. This is our target, Kemble's Kite. Once you have identified it take a look at the star at the kite's northern tip: it is a double star that is easy to split: both its stars are mag.+8.4, and are 103 arcseconds apart. Can you detect any difference in their colours?

Camelopardalis doesn't have any stars brighter than mag. +4.0, which makes it rather indistinct in typical UK skies, so for the next target we'll use the brighter stars of Cassiopeia to star-hop again. We are trying to locate Kemble's most famous object – **Kemble's Cascade**. This time, we imagine a line from Caph (Beta (β) Cassiopeiae) to Segin and, using outstretched fingers as distance markers, extend it for the same distance into Camelopardalis. Without shifting your gaze, raise your binoculars to your eyes; if you don't see the Cascade, you are almost certainly too low, so pan upwards. It is a straight line of 15 mag.+8.0 stars with a brighter mag. +5.0 one in the middle. It extends 2.5° northwest-southeast and has an open cluster, NGC 1502, near the southeastern end. It's vertical during September evenings; imagine a ribbon waterfall with the cluster as a splash-pool at the bottom.

▲ Above left: The Muscleman Cluster takes its name from its stick-man shape

Above right: Kemble's Cascade appears vertical in September, a row of stars extending northwest–southeast

Our next asterism is not immediately apparent in images or on star charts, but it is very obvious in 10x50 or 8x42 binoculars under fairly dark suburban skies. About 3° north of Gamma (γ) Cassiopeiae there is a double-peaked wave of mag. +7.0 or +8.0 stars, '**Eddie's Coaster**', reminiscent of a roller coaster. Eddie Carpenter is the West Country amateur astronomer who found it and showed it to his friends; cast around the sky when you observe and you too may be the first to find something with which you can delight others.

Challenge yourself

Now that you've got the hang of navigating around the night sky, it's time to hunt down something a bit more challenging for our final two targets. First up is the **Little Queen**, a small replica of the W-shaped asterism of Cassiopeia, hence its name. First, you must identify Chi (χ) Draconis and, in the same field of view, 1° towards Tyl (Epsilon (ε) Draconis), you will find a little triangle of mag. +7.0 stars. Either side of the star nearest Tyl, you will see a pair of fainter mag.+8.0 stars that create the 'W'-shape of which the triangle is part.

Keep it steady: make sure you are holding your binoculars correctly

TOP 5 BINO TIPS

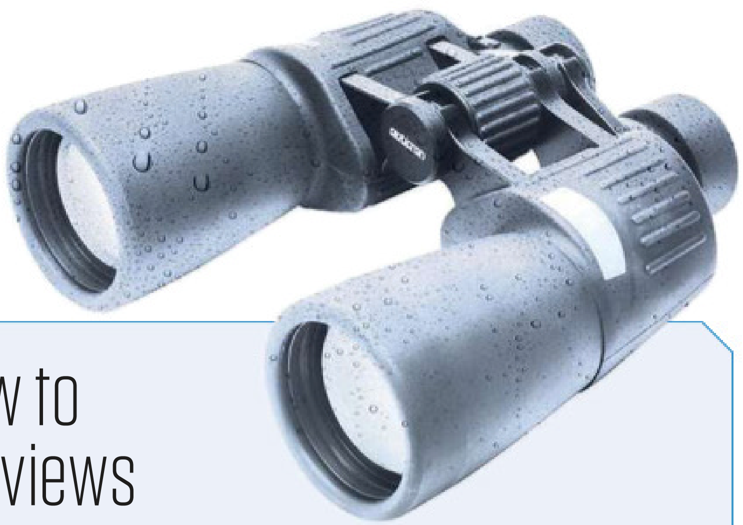
Steady your binoculars

You will see more detail and depth if your binoculars are steady. The simplest way to hold small binoculars steadily is to hold them with your index and middle finger around the eyepieces, the other two fingers around the binoculars' body, and rest the first knuckle of your thumb in the indentations on the outside of your eye sockets. Mounted binoculars are steadier, but tripod legs can get in the way. However, if you use a monopod, which doesn't even need to be vertical to be enormously effective, you can make binoculars up to fairly big 20x80s much more stable.

STEPHEN TONKIN X 6

▲ 'Eddie's Coaster', reminiscent of a roller coaster, was discovered by amateur astronomer Eddie Carpenter

▲ The Little Queen is a small replica of the W-shaped asterism of Cassiopeia



TOP 5 BINO TIPS

Deal with dew to ensure crisp views

Dew will form when moist air meets a cooler surface. Normal binoculars do not have good dew protection for their front lenses. If you mount them, you can use dew-shields made from plastic or foam sheet, but these are awkward for hand-held binoculars.

A common solution is to use a portable 12V hair dryer, which you can run from a battery pack or the 12V socket in a car, as a 'dew gun'. On very cold nights, moisture that evaporates from your eyes can condense on eyepieces; you can reduce this by folding down the eye-cups to allow better air circulation.

▲ Test your observing skills on the tricky North America Nebula, which will be far less distinct than this image

Finally, we come to the **North America Nebula**. To give yourself the best chance of detecting it, wait for Deneb (Alpha (α) Cygni) to be high in a very transparent sky. The nebula's centre is about 3.5° east-southeast of Deneb. You're going to need averted vision, so direct your gaze to the edge of the field of view while you concentrate your attention on the centre. What you are initially trying to detect is the dark nebula that forms the 'Gulf of Mexico'. Once you can see that darker patch, the brighter part of the North America Nebula becomes more apparent.

Practise finding these until they become easy, then try our monthly 'Binocular Tour' (p50) – you'll soon find that you're navigating across the night sky with ease.

TOP 5 BINO TIPS

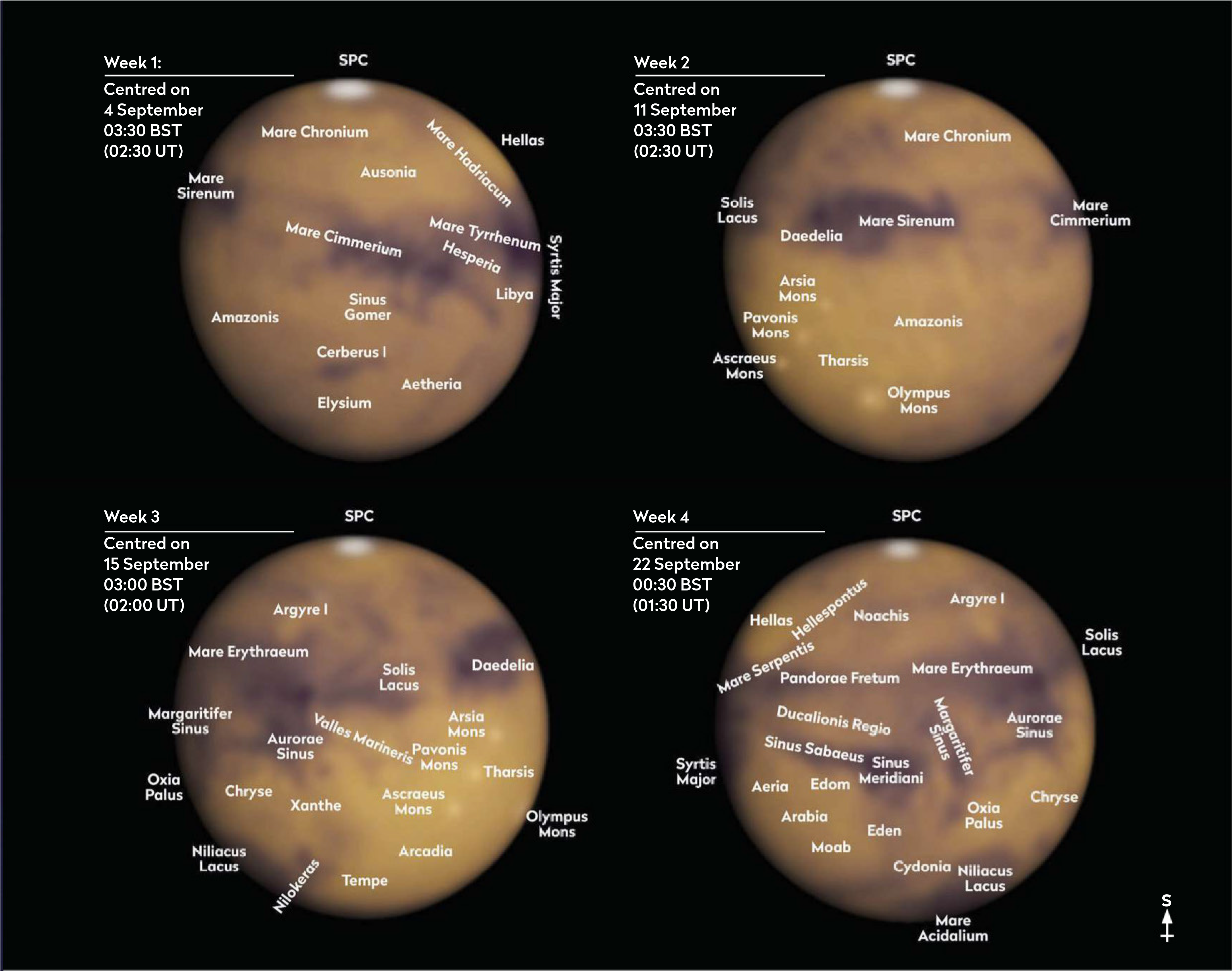
Keep warm throughout the night

It may seem obvious that you need to wrap up warm, but it's always best to dress for at least 5° colder than you think it's going to be; it's easier to cool down if you're too warm than vice versa. Pay special attention to your feet, especially if the ground is wet. If you are going to be standing a lot, pads of insulating mat under your feet can make a tremendous difference. For your torso and limbs, the rule is 'sensible stratification' – layers that can be added or removed for maximum thermal comfort. Ensure that your base layer is made of a fabric that wicks moisture away from your skin.

Don't forget to take a hot drink to help you last the night.

The Red Planet goes RETROGRADE

As Mars's favourable October opposition get closer, watch the planet reverse its apparent motion against the stars this month. **Pete Lawrence** is your guide



▲ Faces of Mars: in the weeks leading up to opposition you can observe different Martian features. A small scope will show the larger markings, while anything over 200mm starts to reveal more detail. In these south-up views Mars rotates right to left with the orientation shown

Mars presents a superb UK observing opportunity in 2020 as the planet reaches opposition at a decent altitude in mid-October. As well as being bright, Mars's apparent diameter will reach a respectable 22.6 arcseconds, a size that will not be approached again until July 2033.

But there's another interesting aspect to opposition, because Mars will be in the middle of a 'retrograde loop' in the sky, and its apparent motion against the background stars will appear to reverse. So far during 2020, its apparent motion against the stars has been eastward, but this will slow to a stop on 10 September, when Mars reaches a 'stationary point'. After this, it tracks west and continues in this direction until another stationary point is reached on 16 November, when Mars resumes moving east. The illusion is caused by the relative position and speed of Mars in its orbit compared to Earth: our faster orbit allows us to overtake Mars, and this creates the looped path in the sky.

All the planets appear to perform retrograde loops, decreasing in apparent size with distance from Earth. And this is the key point: it is Mars's close proximity that makes its opposition and retrograde loop really impressive.

You can reveal the loop by photographing Mars against background stars with a mid- to wide-angle lens on a camera. Take a photograph on every clear night through to the end of the year, load each into a layer-based editor like GIMP and align using the stars. Set the blend mode of all upper layers to lighten and Mars will show through, revealing the loop.

It is Mars's close proximity that makes its opposition and retrograde loop really impressive

Mars in focus

Through an eyepiece, Mars appears impressive during September as its apparent size increases from 18.9 to 22.4 arcseconds. Its darker albedo markings and bright southern polar cap (SPC) should be obvious with magnification. Bathed in sunlight over past months, the SPC will have reduced in size and during September appears small. As it shrinks, the 'Mountains of Mitchel' become visible; a bright region ▸

ALL PICTURES: PETE LAWRENCE

Imaging the Red Planet

How to capture clear images of Mars when it's high and bright

When it's close to a favourable opposition, Mars is a great imaging target. For best results you need a planetary camera that can record many still frames in rapid succession. These can then be processed using freeware programs such as AutoStakkert! or RegiStax. The larger aperture of telescope you can use, the better. Allow your scope time to cool before use, typically 1–2 hours (large scopes may need longer). When imaging, re-focus after each filter change and ensure focus is accurate.

A colour camera or monochrome camera with filters, eg, RGB (Red, Green, Blue), is ideal. However, colour can suffer from atmospheric dispersion, an effect that chromatically blurs detail. This worsens the closer you get to the horizon, fine detail becoming less distinct and colour fringes appearing, but these effects can be reduced by using an atmospheric dispersion corrector (ADC).

Mars withstands seeing conditions well due to much of its light being in the redder, longer-wavelength part of the spectrum. If your camera is infrared (IR) sensitive, an IR-pass filter can also deliver sharp, high-contrast results.

▲ On target: a planetary camera is ideal for imaging Mars as it can record many still frames in rapid succession

Optimum focal lengths are dictated by camera pixel size. For decent seeing, an image scale of 0.25 arcseconds/pixel is recommended. For superb seeing, 0.1 arcseconds/pixel may also work. The best focal length can be calculated from: FL = (Ps x 825) for 0.25 arcseconds/pixel, or FL = (Ps x 2060) for 0.1 arcseconds per pixel; where FL = telescope focal length (mm) and Ps = pixel size (microns).

Close to opposition, Mars rotates 0.25 arcseconds in about 5 minutes and 0.1 arcseconds every 2 minutes. Consequently, cumulative capture times (eg, total for R+G+B) must be shorter to avoid rotational motion blur.

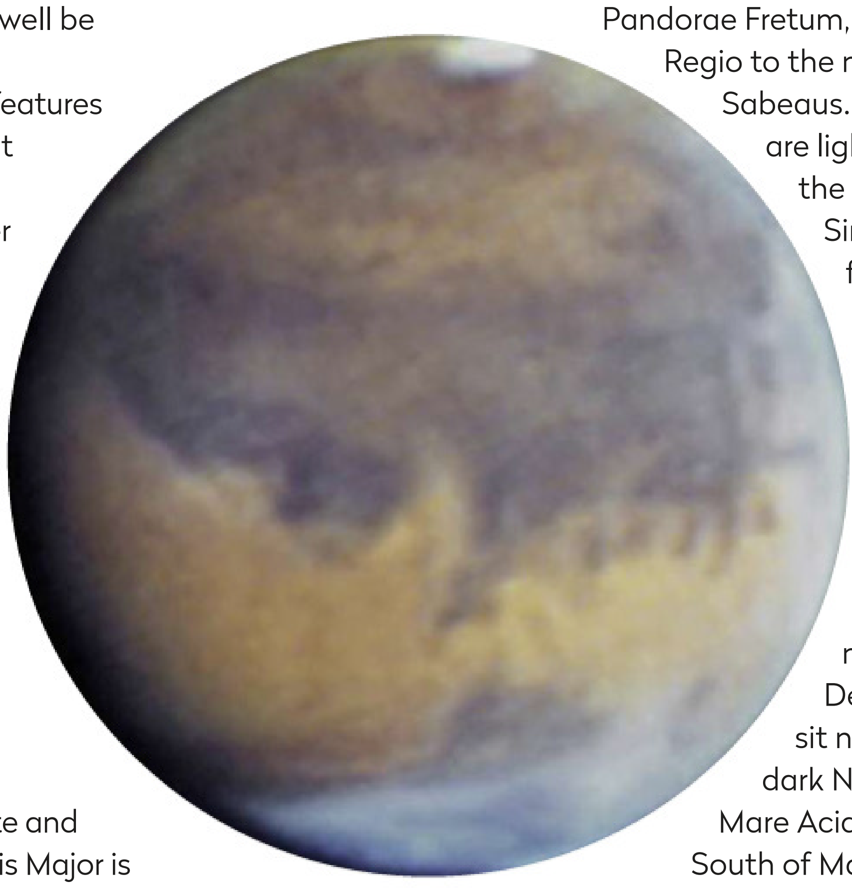
▸ that in reality is a plain, it appears detached from the SPC, south of Hellas.

At the opposite pole, the northern polar cap (NPC) is cooling and as it does, a shroud known as the north polar hood (NPH) forms above it. The southern edge of the NPH may well be visible during September.

Amateur telescopes show albedo features – dark areas of exposed rock and light areas of desert sands. Imaging under excellent seeing with a telescope over 300mm in diameter may hint at large relief features such as giant craters Schiaparelli and Herschel or the impressive Valles Marineris canyon, but in general what you're recording are albedo features. Martian weather clouds may also appear and are often better seen close to the limb and terminator of the planet.

Take a tour

The features you'll be able to see on the disc will be dependent on the date and time you're observing. V-shaped Syrtis Major is prominent and well presented during this apparition (the current observing window of an object). Clouds tend to form in an equatorial band, possibly reducing the intensity of Syrtis Major. Known as the 'Syrtis blue cloud', this is best seen as Syrtis Major approaches sunset. South of Syrtis Major is the giant Hellas basin, its western edge defined by Hellespontus, the eastern edge by Mare Hadriacum.



▲ An inverted image of Mars through a 250mm telescope, shows the north polar hood (bottom)

Extending west at a tangent to Hellas's northern boundary is Mare Serpentis, eventually merging with Pandorae Fretum, bordered by lighter Deucalionis Regio to the north. Further north lies dark Sinus Sabeaus. Aeria, Arabia, Moab and Eden are light desert regions to the north. At the western end of Sinus Sabaeus sits Sinus Meridiani, a dark rectangular feature with two north-pointing 'prongs'; it marks the zero point of Martian longitude.

After a lighter patch west of Sinus Meridiani comes dark Margaritifer Sinus with Oxia Palus to its north. West of Margaritifer Sinus is dark Aurorae Sinus, bordered to the north by numerous finger-like extensions. Desert regions Chryse and Xanthe sit north, bordered to their north by dark Niliacus Lacus and eventually Mare Acidalium.

South of Margaritifer Sinus and Aurorae Sinus, extending west of Pandorae Fretum, is Mare Erythraeum with the large Argyre basin to its north. West of Aurorae Sinus is the 'Eye of Mars', the central feature being dark Solis Lacus. The immense Vallis Marineris canyon lies northeast of Solis Lacus.

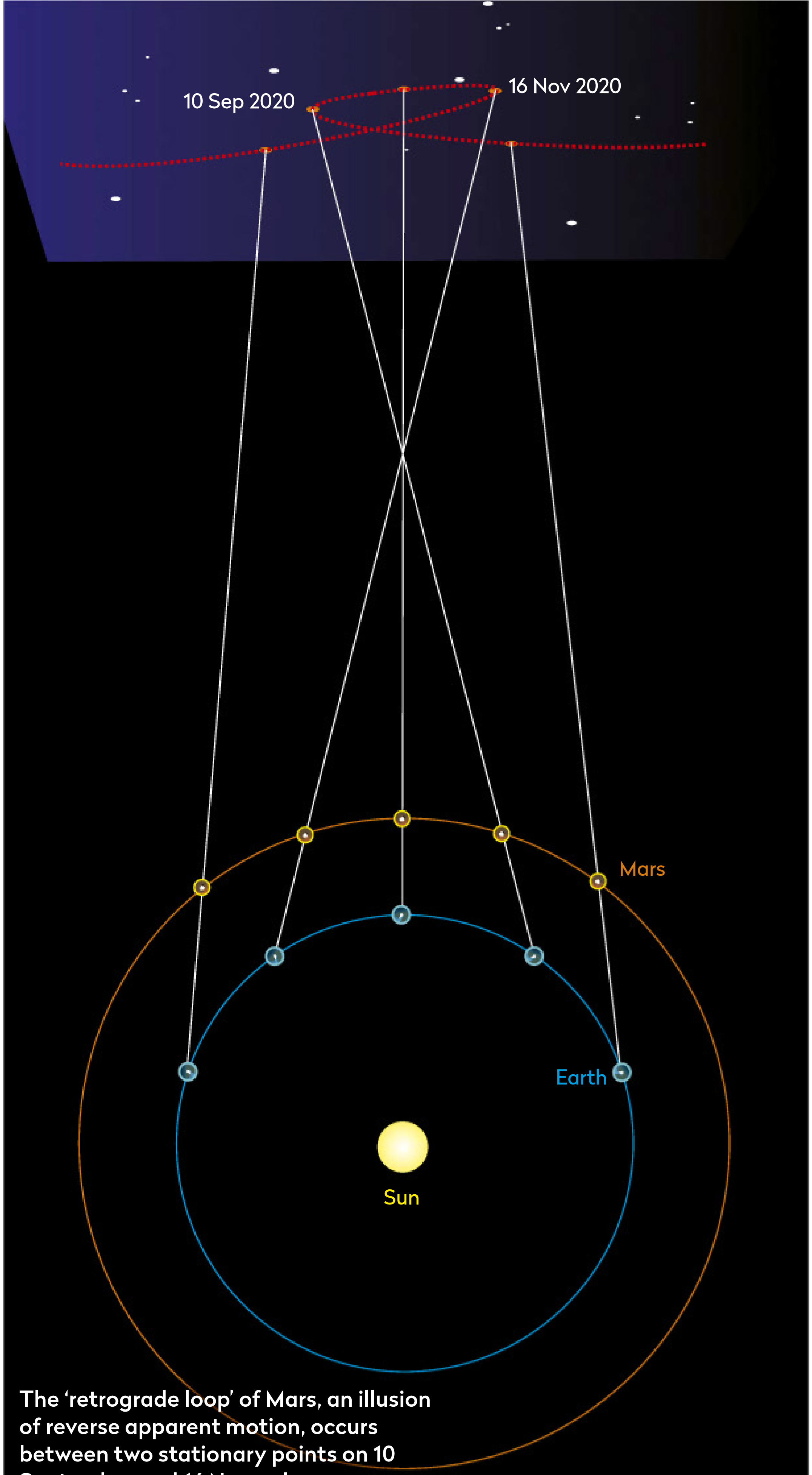
ALL PICTURES: PETE LAWRENCE

The desert expanses of Tharsis and Amazonis lie northwest of the 'Eye of Mars'. Here three volcanic peaks named (north-to-south) Ascraeus Mons, Pavonis Mons and Arsia Mons define the southwest edge of the 'Tharsis quadrangle'. Arranged in a line, they look northwest over the vast volcano Olympus Mons. Bright orographic clouds may form when the Martian atmosphere is forced upwards over these volcanos. These sometimes coalesce on the evening side, forming a south-up 'W'. A blue or violet filter (W38 up to 250mm, W47 for larger apertures) helps reveal this.

West of Solis Lacus is Mare Sirenum, eventually leading into Mare Cimmerium with its north-pointing dark protrusions of Sinus Gomer. West of Mare Cimmerium is lighter Hesperia, dividing Mare Cimmerium from dark Mare Tyrrhenum. The latter eventually joins to Syrtis Major, where we started.

Dust storms may be seen as lighter patches, often yellowish in colour, and they occur seasonally. The way seasons are marked on Mars is to use solar longitude (Ls), the Mars–Sun angle. Storms occurring between Ls = 270° to 359° (northern winter) can be large and Mars will be in that season: in September Ls = 269° to 288°, while in October Ls = 288° to 307°. Large planet-engulfing storms are fortunately rare; whether we will get one we'll just have to wait and see.

Pete Lawrence is a skilled astro imager and a presenter on BBC Four's *The Sky at Night*. He writes for the magazine's Sky Guide found on page 39



The 'retrograde loop' of Mars, an illusion of reverse apparent motion, occurs between two stationary points on 10 September and 16 November

Making an observation

Augment your views of Mars for useful scientific study

Making an observation of Mars isn't hard. Make it useful for wider reference by recording the date and time (in Universal Time, UT). Include your name, location and conditions, making a seeing estimate through the eyepiece. The five-point Antoniadi scale (see table, right) is useful for this.

Record the observing instrument along with details of magnifications used. Also record whether filters were used. Images and drawings are normally (but not exclusively) presented south-up with the following (F) and preceding (P) limb directions indicated. Features rotate into view around the F limb, disappearing behind the P limb.

It's optional but useful to include values for solar longitude (Ls) and the planet's central meridian longitude (CM). Get these from a program such as the freeware WinJUPOS, Once completed, submit your efforts to an organisation such as the British Astronomical Association (BAA) Mars section or the Association of Lunar & Planetary Observers (ALPO).

The Antoniadi scale

I	Perfect stability
II	Slight quivering
III	Moderate steadiness with large air tremors
IV	Poor stability
V	Very poor stability

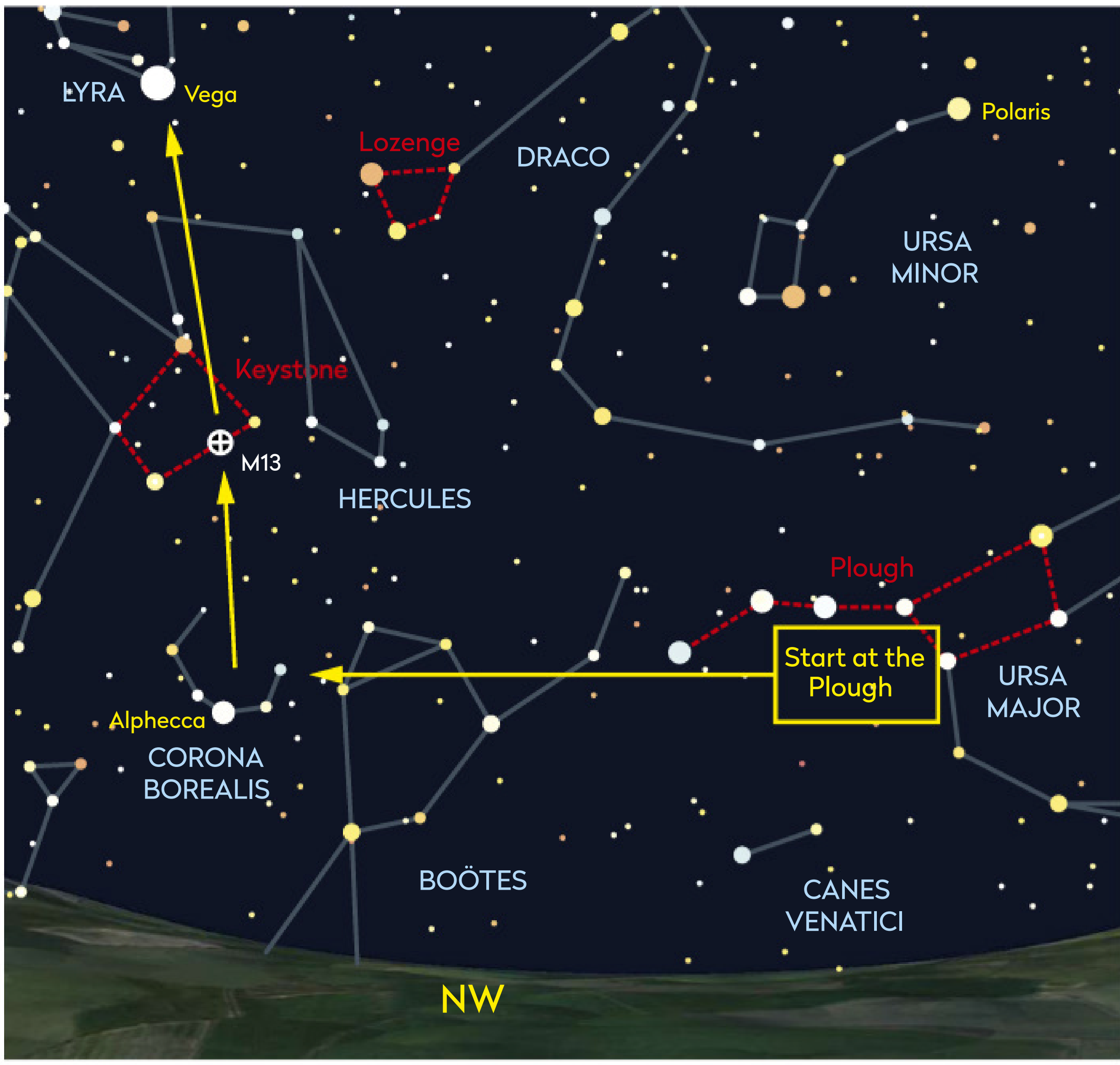
▲ Record the quality of seeing during your observations of Mars

The fundamentals of astronomy for beginners

EXPLAINER

Get to know the constellations of autumn

Join our easy, naked-eye tour of the brighter, recognisable constellations that are visible in the September night sky



▲ **Corona Borealis is low in the west but it's a stunning sight once you find it. Halfway between its brightest star, Alphecca, and bright Vega is the Hercules Globular Cluster, M13, which is beautiful in binoculars or a small telescope**

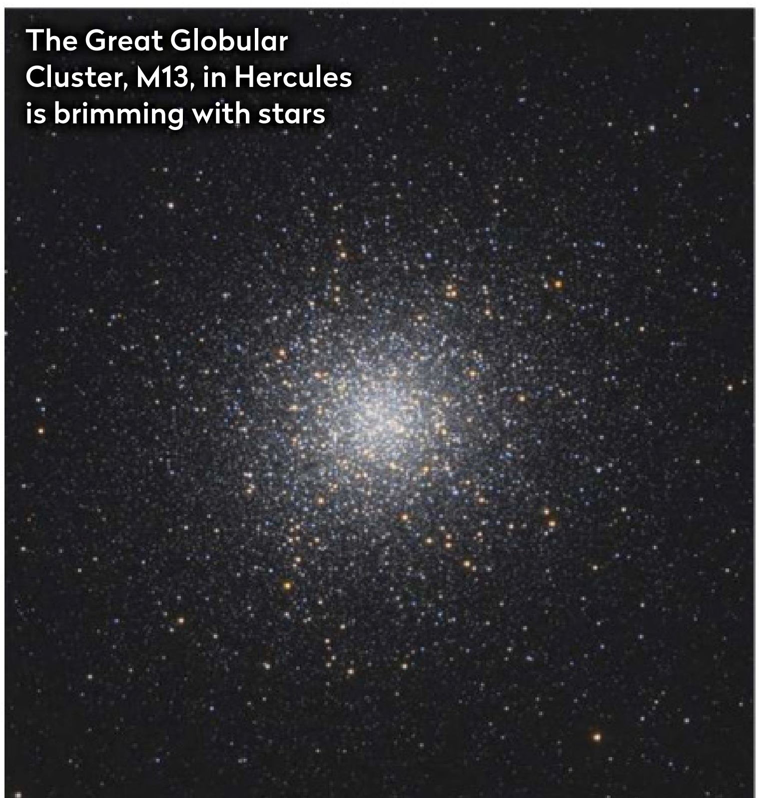
Although it's hard to believe, we're only a matter of weeks from the equinox, on 22 September, and the start of autumn. As the seasons change let's take a tour of this month's skies and we'll see spring and summer's stars making way for the stars of the dark-sky season. Just take this article with you as you head out and keep turning to your left, from your starting point facing northwest, hopping from star to star as you read along. As you do, you'll see the seasons' stars change before your eyes. This constellations guide is accurate for the UK at about 22:00 BST (21:00 UT) at the start of September, and 20:00 BST (19:00 UT) by the month's end. Enjoy the tour!

Scott Levine is a US naked-eye astronomy enthusiast based in New York's Hudson Valley. Read his blog at **scottastronomy.wordpress.com**

1. NORTHWEST AND WEST

We'll start by facing the northwest and locating our first target, the Plough. This month, the Plough skirts just above the horizon, near the bottom of the path it appears to trace around Polaris (the North Star). As time goes on, we can watch it turn and gradually swing upwards and towards the east.

Turning towards our left, we'll see some of the last of spring's stars. Crossing the dim stars of Boötes, the Herdsman, we reach my favourite small constellation: the C-shaped Corona Borealis, the Northern Crown. Directly above Alphecca, this constellation's brightest star, are the dim stars of Hercules. I often find these tricky, but if you are scanning the skies above Alphecca with a pair of binoculars or a small telescope, you may be able to find the hundreds of thousands of suns of the Great Globular Cluster, M13, about halfway along the line upwards to Vega.



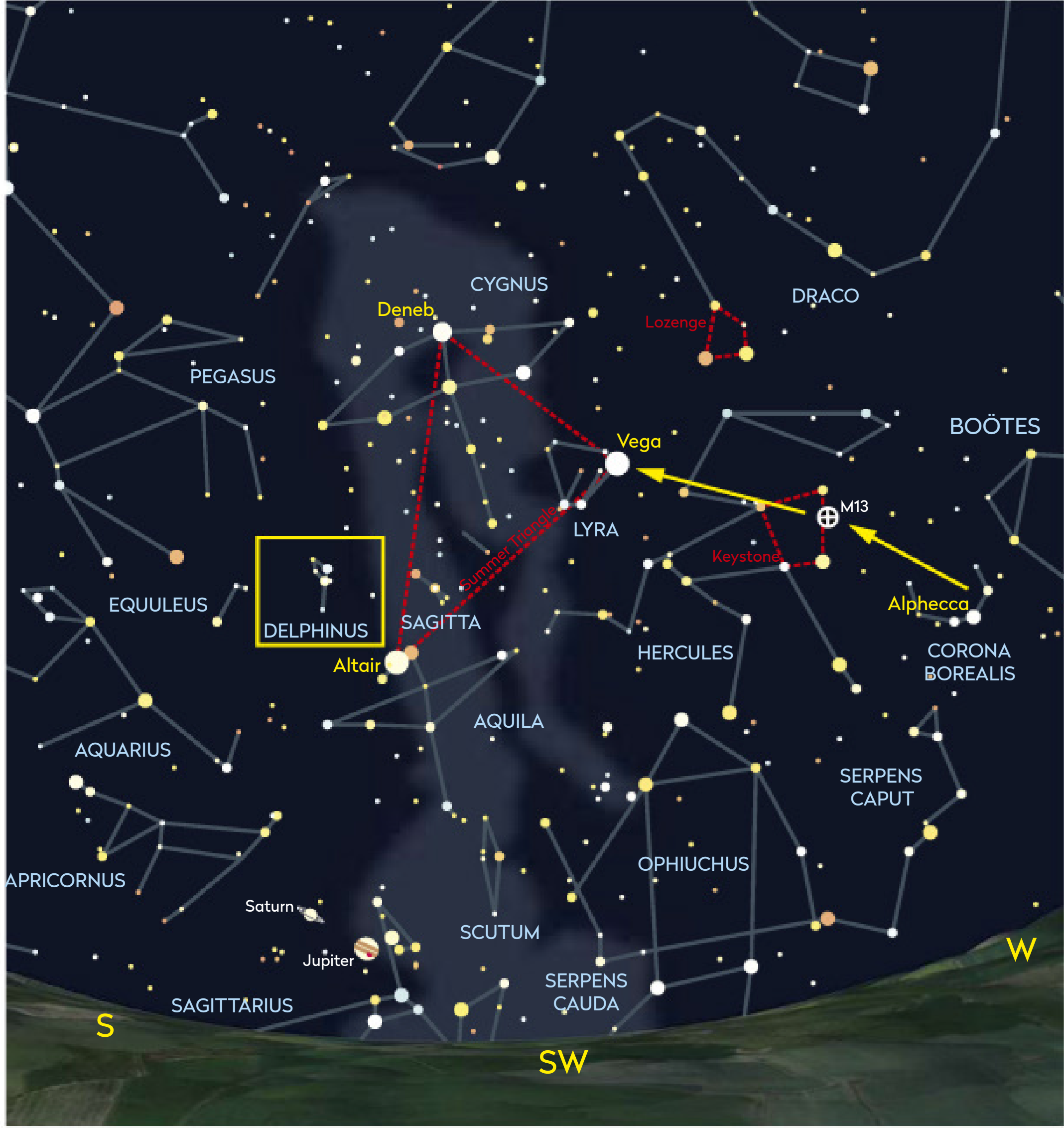
The Great Globular Cluster, M13, in Hercules is brimming with stars

CHARTS BY PETE LAWRENCE, MARKUS BLAUENSTEINER/CCDGUIDE.COM

2. SOUTHWEST AND SOUTH

Now keep turning towards the left and look almost directly overhead. High towards the southwest in Lyra is the star Vega. Then, very high and nearly due south, you'll find Deneb in Cygnus and Altair below, in Aquila. It was only a few weeks ago when these, the bright stars of the Summer Triangle, soared high overhead. Now they're already setting when darkness comes. Altair and Vega are relatively close to us – only about 16 and 20 lightyears away – but Deneb is about 2,600 lightyears away, so it looks mellower and more subdued than the other two.

From the Summer Triangle, look for the small constellation of Delphinus nearby. Its stars almost look like a small dolphin, with a diamond-shaped head and a long tail, swimming upstream along the Milky Way, which runs through this stretch of sky.

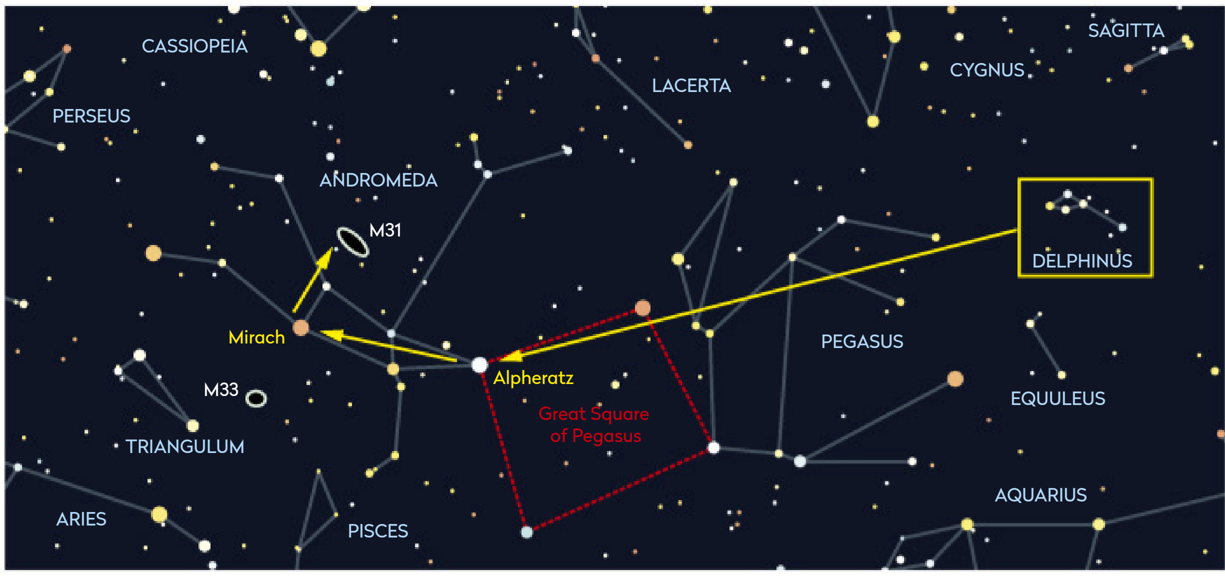


► **The area near the Summer Triangle is rich with deep-sky objects, including the band of our own Milky Way. It's easy to get lost for hours here, scanning the sky and seeing what you come across**

3. SOUTHEAST AND EAST

As we cross into the southeast, we're in the rising part of the sky, where the newcomers are. Here, we'll find the Great Square of Pegasus. Its eastern-most star is Alpheratz, which is the brightest star in the constellation of Andromeda, the mythological princess. Andromeda's main stars lie more or less parallel to the horizon, like they're underlining the upper sky. Two star hops east (toward the left) of Alpheratz is Mirach (not to be confused with the Plough's Merak).

If you have a pair of binoculars, aim them about 7° – a bit less than a fist at arm's length – above Mirach. Hiding 2.5 million lightyears away in that seemingly empty patch is the Andromeda Galaxy, M31. Under city and suburban skies, it looks like a thumbprint on the sky and might surprise you the first time you spot it. Once you see it, though, you'll go back again and again.

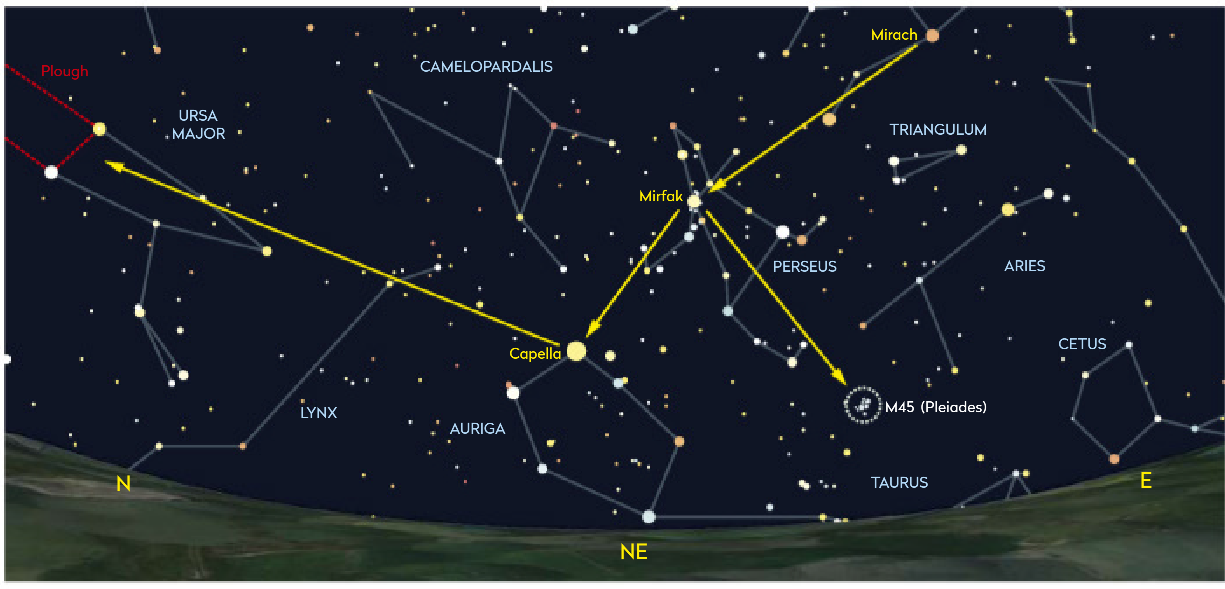


▲ **The Andromeda Galaxy is a fun target for beginners to search for. It's surprisingly easy to find, even under suburban skies. Once you do spot it, it's amazing to imagine that you're looking at 2.5-million-year-old light.**

4. NORTH AND NORTHEAST

As we turn towards the northeast, let's follow the line of Andromeda's stars downwards and to the left, to Perseus and its brightest star Mirfak. As we continue down that line towards the horizon we can look for the gorgeous yellow star Capella (the brightest in the constellation of Auriga) and the Pleiades Cluster, M45, just a short way above the horizon as September progresses. It won't be long before they're high above us on another freezing January night, along with the rest of the bright winter lights, but September gives us a sneak preview as they make their way higher into the nights.

From here it's just a short turn back to where we started, the Plough. September is a time of change in the weather and in the skies. We hope you enjoyed this hop around the stars and you'll be inspired to take a look at these sights this month.



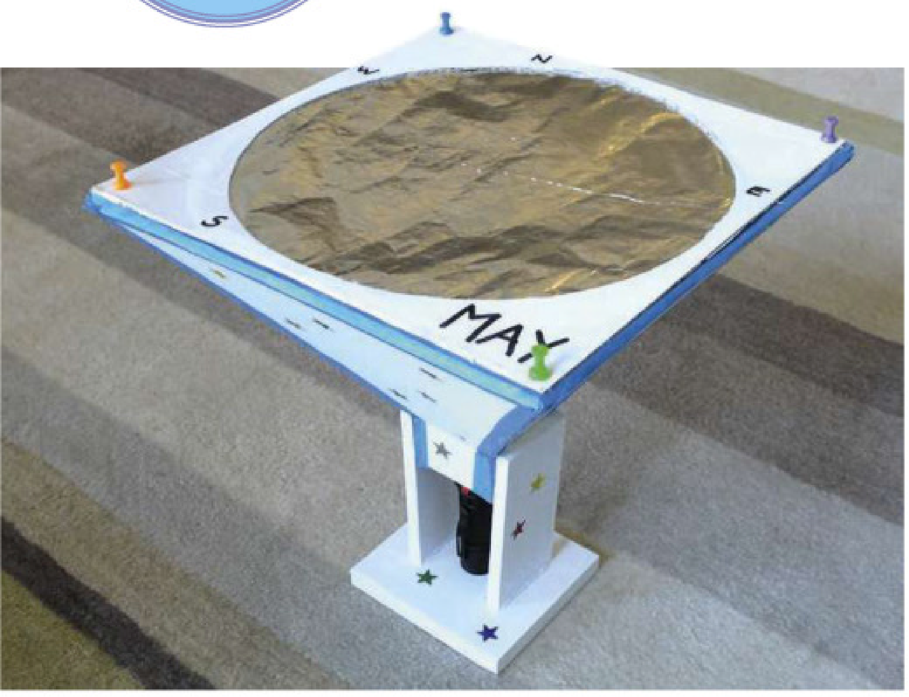
▲ **Though we usually think of Capella and the Pleiades as winter stars, they start to rise higher into the skies this month. Few things in the night sky are more amazing than the Pleiades through a pair of binoculars.**

DIY ASTRONOMY

FAMILY FRIENDLY PROJECT

Build a planetarium projector

Create an indoor view of the night sky by projecting the magazine's all-sky chart



◀ **Star maker: the completed planetarium projector uses the monthly all-sky chart to create an illuminated star field**

More ONLINE

Download diagrams and photos for this project. See page 5 for details.

This month we've got a family friendly project that you can build with minimal tools and basic skills. It's a planetarium projector that projects a view of the night sky onto a bedroom ceiling. It uses a normal LED torch as a light source and the pull-out all-sky chart from our monthly 'Sky Guide' (on page 46) to position the pinholes you make for the stars. As well as being fun to make it's educational, as you can use it to learn how to navigate between the constellations. And by making multiple pinhole 'slides' you can demonstrate how the sky changes through the seasons.

Filling your room with stars

To use the projector, find a clear space on the floor for the torch in its base. Next, place the box over the torch, lay a night-sky slide on the top and switch on. You could orientate the projector so that the compass points (north, east, south and west) correspond with the edges of the ceiling. It is important to use a torch with a single, small light source (an LED or tiny bulb) and it should also produce a fairly wide beam. Our torch had a 'Zoom' feature and we used it on the widest setting. Before starting the project, you need to hold your torch just above the chart so that its circular beam of light just spills beyond the chart's edge, and measure the distance (h) between the torch and chart. You'll need this dimension (h) for the downloadable diagram (see page 5 for details) to mark out your box sides.

The box and slide frames are made from some stiff cardboard. After cutting out, we used a hot-melt glue gun to join the sides, but strong tape would be fine. The inside must not create reflections, so we combined sawdust and matt black paint to overcome this. It is easier to paint the insides before gluing the top section on.

The stand will need to suit your torch, but a fairly heavy base with a hole that the torch can be stood in is a simple solution. Two walls made from offcuts of wood hold the box above the torch, so that the top of the torch just reaches the fold line of the box, close to the distance (h) from the slide at the top.

Next, paint the underside of some foil matt black and mount it to a cardboard slide with a glue stick, and you are ready to start making the holes for the stars. You need to work on the foil's underside or you will find your east and west are reversed when you project the stars: so place the sky chart over the black side of the foil and begin making the pin holes. You need the tiniest holes you can possibly make; we estimate that the resulting stars are about 10 to 20 times the size of the holes you make, so small is beautiful.

You may not want to pick out all the stars on the chart; you might, for example, decide to just include the main constellation stars. If you are very careful you can vary the hole sizes to emphasise bright stars or pick out planets for added effect.

Mark Parrish is a bespoke designer. See more of his work at: **buttondesign.co.uk**

What you'll need

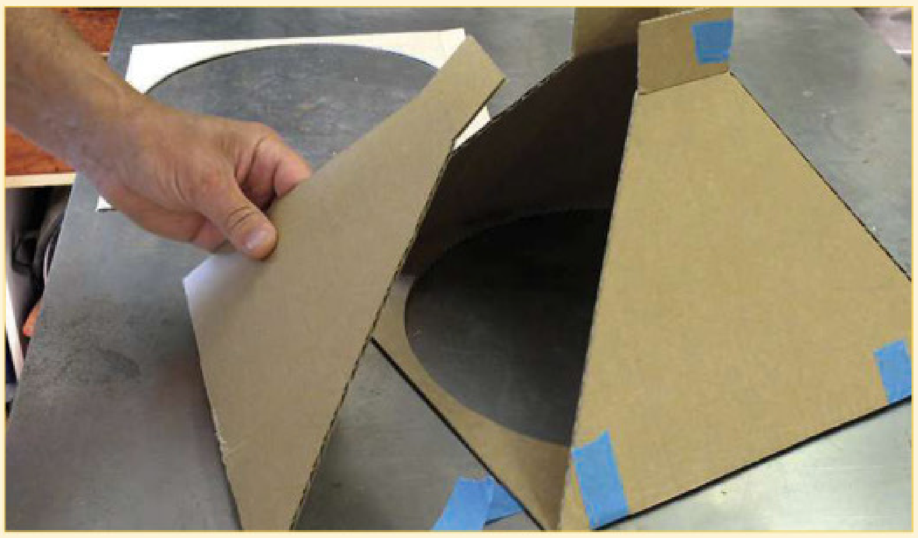
▶ Marking out tools (a ruler, compasses and a pencil), a craft knife and cutting mat, scissors, masking tape, a hot-melt glue gun (or strong adhesive tape), a small saw and drill for making the wooden base, a small dressmaking pin and a glue stick.

▶ Several sheets of stiff or corrugated cardboard (old packaging) – at least six sheets, approximately 300 x 300mm in size, some aluminium foil and a few small offcuts of wood.

▶ Sundries include a small, bright torch with a single LED or very small bulb (not an LED array), plus a copy of the all-sky chart from page 46.

▶ For the finish you'll need matt black spray paint for the interior of box, foil and sawdust, plus suitable paint and decorations for the outside.

Step by step

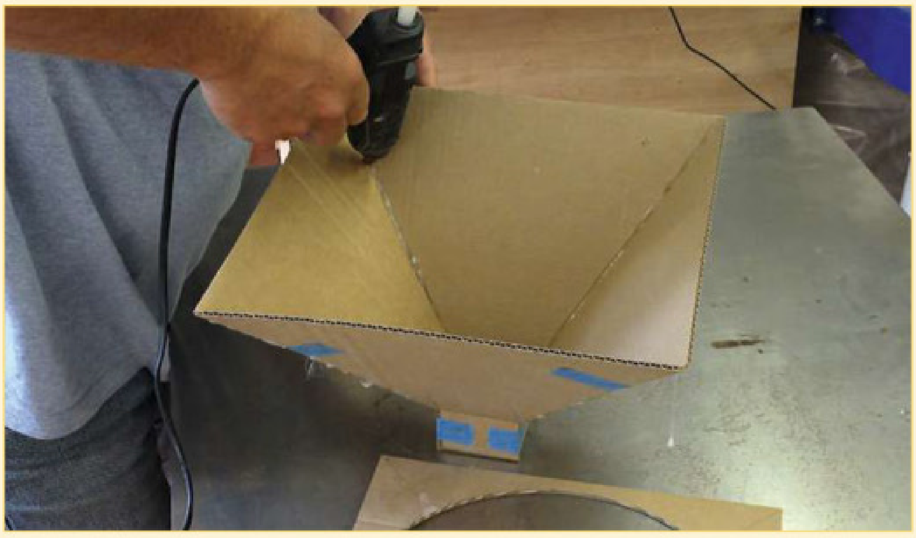


Step 1

Test the torch and use our downloadable diagram (see page 5) to work out the size of the projector box. Mark out the sides and top of the box. Carefully cut them out with a craft knife (adults only) and remember to always cut away from your other hand.

Step 2

Make additional 'tops' – you need one for the box and one for each monthly sky 'slide' you plan to use. Use small pieces of masking tape to fit the box pieces together. Score the sides so they fold neatly near the narrower torch end.

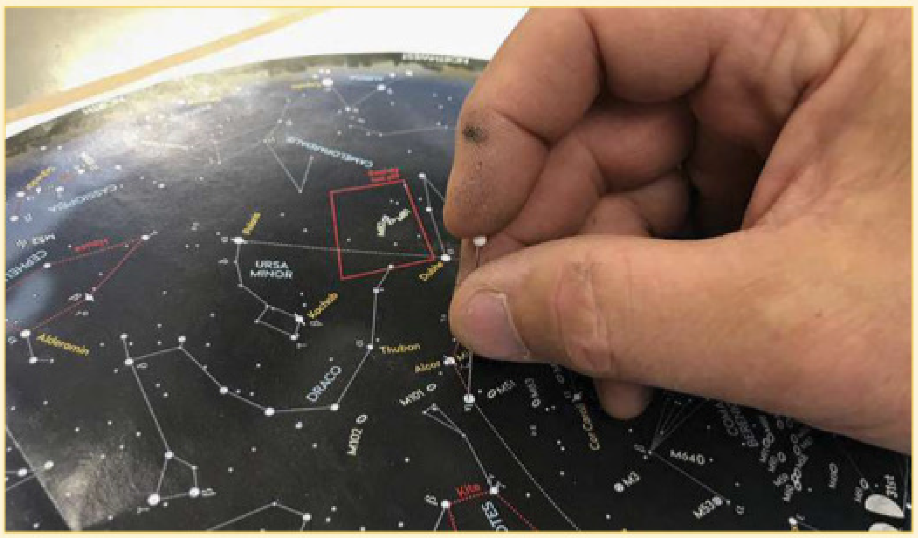


Step 3

Use the glue gun to join the side pieces together. After running the glue down the outside, remove the top and glue the inside to make a rigid structure. Remember to take care with the hot glue. You can also use strong tape if you don't have a glue gun.

Step 4

You need to stop any reflections inside, so paint the interior of the box and top piece matt black. While the first coat is wet, sprinkle on some sawdust, shake off the excess and then apply another coat. This should create a light-absorbing surface.



Step 5

Use some offcuts of wood to make a stand for the torch. We drilled a hole in the base for the torch to stand in. The top of the stand's two 'walls' should be just below the top of the torch and the width between them should match the box 'neck'.

Step 6

Glue the top of the box on. Paint one side of the foil matt black then, with the black side facing down, stick it to the monthly 'slide'. Place your pull-out all-sky chart over the black side of the foil and make tiny pin holes through the chart and foil.

Take the perfect astrophoto with our step-by-step guide

ASTROPHOTOGRAPHY CAPTURE

Catch a month of beautiful conjunctions

Make the most of these wonderful photo opportunities with a smartphone or a camera

▲ **Bright encounter: a clear night can provide a perfect opportunity for a conjunction photo, like this pairing of Jupiter and the Moon**

Conjunctions occur when two or more heavenly bodies appear close to each other in the night sky. It could be a conjunction of two or more planets, or planets and the Moon, or Solar System objects near deep-sky objects. This month several conjunctions take place, and we're looking at the best ways to capture them.

Solar System conjunctions are great targets for astrophotography because they often involve bright subjects. The planets Mercury, Venus, Mars, Jupiter and Saturn fall into this category. Add the Moon and you have objects which are bright enough to be captured on a smartphone or a more sophisticated camera.

The Moon is a great conjunction maker; it passes around a narrow corridor of sky centred on the ecliptic once every 27.3 days relative to the background stars and encounters each planet. This means there is often a good opportunity for a conjunction image. Capturing the Moon with a wide-field camera can be a humbling experience as the Moon's apparent size in the sky is just half a degree across. If you want to do this as well a catch a nearby planet, a longer focal length is often required.

There are various ways to make your shots stand out. One is to predict where the conjunction objects are going to appear in the sky relative to a foreground object like a tree or a building. The motion of everyday life below the conjunction can also add an extra dimension to a shot: set the camera's sensitivity a bit lower than normal and try an extended exposure. A shot set up with a road or street between you and the camera will show the conjunction with human movement below it.

Stopping a lens down on bright objects can add drama. The aperture blades in some lenses produce dramatic diffraction spikes, but stopping down does mean less light is entering the camera. This means that either the ISO needs to be set higher, introducing more noise, or the exposure lengthened, risking motion blur. To get round this set the camera up on a tracking mount. Piggybacking on an equatorially mounted and driven scope will achieve this. A dedicated equatorial camera mount also works.

With so many conjunctions due this month, there's a good chance that we will get windows of opportunity even if the clouds get in the way for some events. If the forecast isn't great, it can pay to be vigilant, capturing what you can through any gaps. Good luck and don't forget to send us your results.

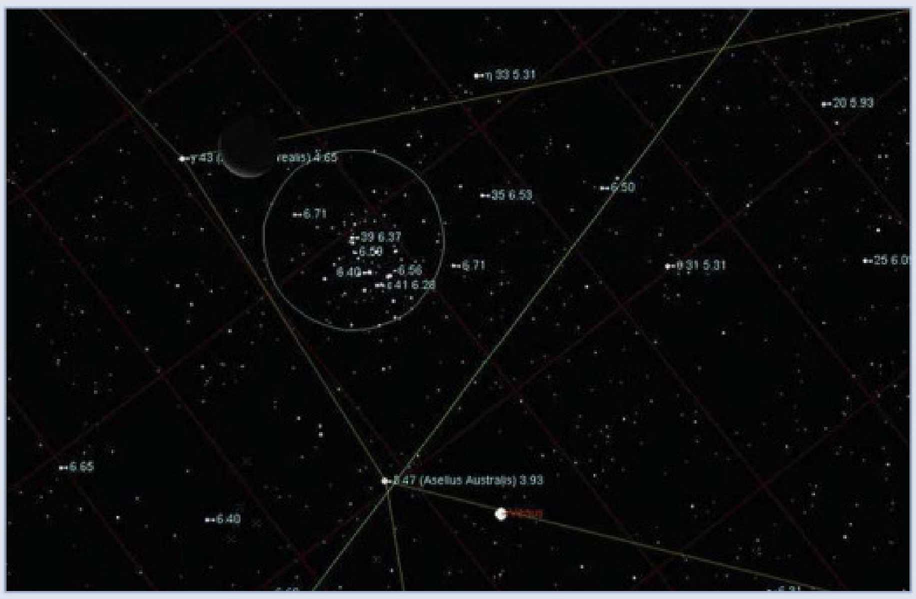
Recommended equipment: a smartphone, DSLR or MILC camera and a tripod mount

▸ *See page 42 for details of this month's conjunctions*

Pete Lawrence is an expert astro imager and a presenter on *The Sky at Night*

Send your images to: gallery@skyatnightmagazine.com

Step by step



STEP 1

Pre-planning is essential for conjunction photography. One of the first things to work out is how far apart the objects will be, and whether it's possible to bring something else into the shot, typically a foreground target, to give some context. Here, a planetarium program and field of view calculator are your main tools.

STEP 2

First, determine the apparent separation of the conjunction targets and the altitude of the scene using your planetarium program. Then determine a rectangle big enough to contain everything you want in the shot with a bit of leeway. Next, use the field of view calculator to find the correct lens size to give you this coverage.

STEP 3

Determine a good location to photograph the conjunction from. It may sound obvious, but check to make sure there are no foreground objects in the way. Check the weather forecasts for the conjunction date. If the forecast is poor, check how close the objects concerned will be before and after the closest date. For the planets, the difference may not be that significant.

STEP 4

If you plan on capturing a wide-field shot, a tripod mount will often suffice. Use the '500 rule' if you want to avoid trailing; divide 500 by your focal length to work out the longest exposure you can take without trailing being noticeable. If you use a smartphone, place it on a static platform or use a tripod mount and this will help too.

STEP 5

For conjunctions with fainter objects, for example Venus and the M35 open cluster, a tracking mount is recommended. This allows you to keep ISO settings at the low- to mid-range, avoiding noise and maintaining tonal integrity in the image. Depending on how accurate your polar alignment is, a tracking mount will allow you to expose for several seconds without motion blur.

STEP 6

Use a remote shutter release to take your shots without vibrations. On many smartphones you can use the volume control on wired earphones as a remote shutter release button. Take shots on the nights before and after conjunction to use as reference images to show just how the scene has changed over time."

Expert processing tips to enhance your astrophotos

ASTROPHOTOGRAPHY PROCESSING

Using Photoshop masks to enhance a nebula

Discover how masks can help you apply enhancements to specific areas of your astro images

▲ **...and after: the final image of the Heart Nebula, IC 1805, enhanced by using Photoshop's mask features**

▼ **Before: with its 'Levels' adjusted, our nebula image is ready for demonstrating Photoshop's mask techniques**

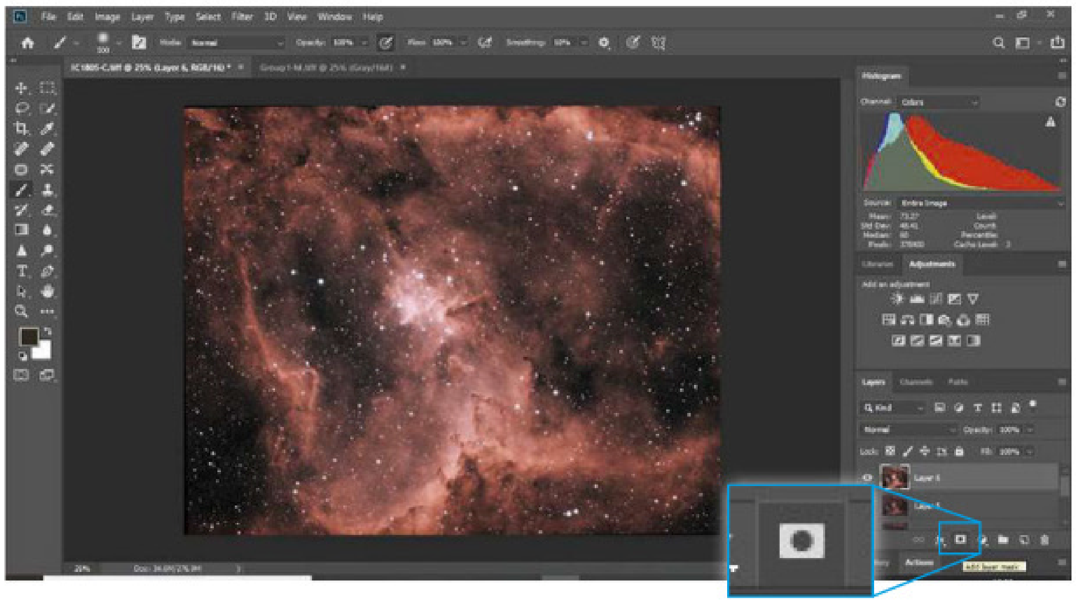
Masks can be found in many image processing and editing software apps. Here we take a look at how they can be used in Adobe Photoshop to improve an image of the Heart Nebula, IC 1805. Photoshop masks allow us to cover an adjustment we make to an image with a screen and control the areas in our final image where the adjustment shows through. By using masks, we can be specific with our image enhancements. Two popular masks for astro-processing are 'Hide All' and 'Reveal All' masks. These are found in the 'Layer' menu ('Layer › Layer Mask') or accessed via shortcuts, which is covered later in the article.

'Hide All' and 'Reveal All' masks perform opposite functions. After carrying out an adjustment on a new layer, 'Hide All' masks create a screen from the previous, unaltered layer, and place it on top of the adjustment. This means that you can select areas where you want the change to appear by 'rubbing' through the screen. Meanwhile, 'Reveal All' masks use the adjusted layer as the screen, placing it on top of a copy of the preceding layer. This allows you to select the areas you don't want the change to appear. Out of the two, we use 'Hide All' masks more often.

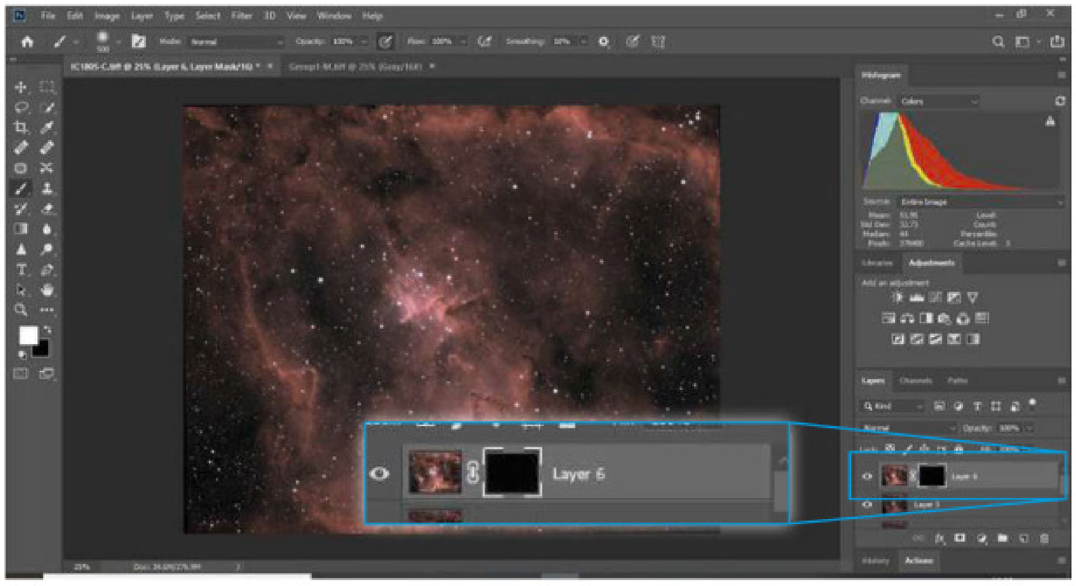
ALL PICTURES: CHARLOTTE DANIELS

Applying masks

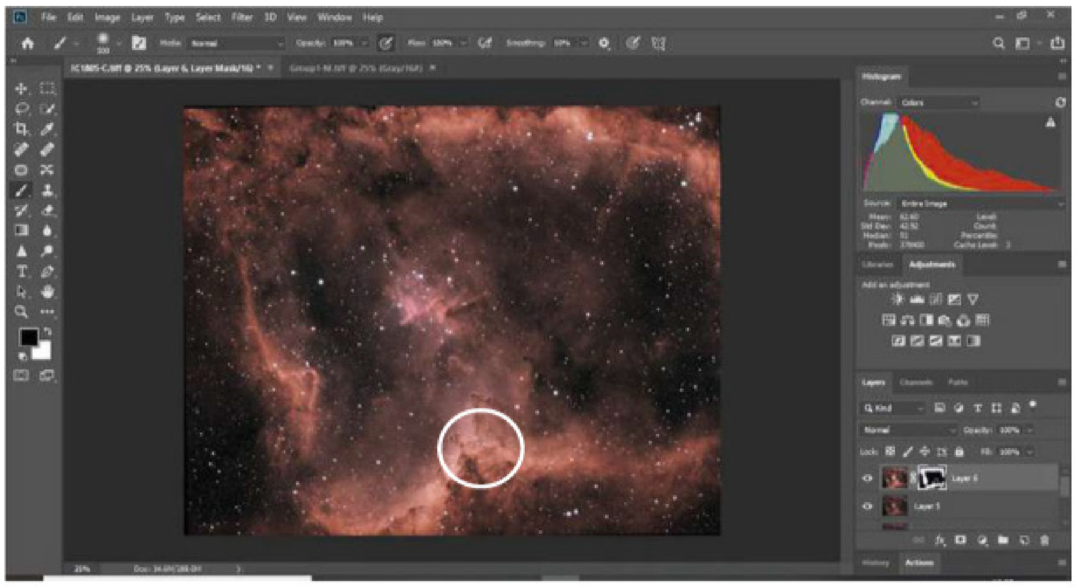
Applying 'Hide All' and 'Reveal All' masks in Photoshop consists of several stages. The first involves creating a new layer on which you perform adjustments (press 'Ctrl, Shift, Alt, N and E' simultaneously for this). In this example we are using an image of the Heart Nebula, IC 1805, to demonstrate a 'Hide All' mask. We've used the 'Levels' function ('Image › Adjustments › Levels') to stretch



▲ **Screenshot 1: the 'Hide All' mask is applied by clicking the mask button under the layers; this allows you to make adjustments to specific areas of an image**



▲ **Screenshot 2: with a 'Hide All' mask, a black screen appears next to the layer – your adjusted layer is now placed beneath the original image**



▲ **Screenshot 3: brush areas on your original image (top layer) to bring in adjustments from the lower layer**

the image (see opposite, top right) and we are now ready to get more precise with our adjustments.

The second stage is to perform an amendment via Photoshop's 'Adjustments' menu ('Image › Adjustments') and adding the adjustment into the new layer (right click and select 'Merge Down'). We want to boost the brightness of our image and increase the contrast of some of the nebulosity. Screenshot 1 shows our Heart Nebula image after the 'Brightness/Contrast' function is applied and merged. However, we only wish to make this adjustment to some outer parts of the nebula – not the core, which is now overexposed.

This is when we can apply our mask. In this instance, we will use a 'Hide All' mask because it will allow us to 'brush in' the 'Brightness/Contrast' change to the areas we want. A shortcut to the 'Hide All' mask is to press 'Alt' while clicking the mask button (indicated in Screenshot 1). This is in the toolbar directly under your layers. (To get a 'Reveal All' mask, click on this icon without pressing the 'Alt' key).

Charlotte Daniels is an amateur astronomer, astrophotographer and journalist

3 QUICK TIPS

1. If only making changes to small areas of the image, use the 'Hide All' mask and a small brush.

2. Don't worry about being too accurate with your brush strokes – applying a blur softens their edges.

3. Use the square bracket keys to quickly alter the size of the brush used with your masks.

Making adjustments

For the 'Hide All' mask you'll notice this action makes the main image revert back to its appearance before we made our adjustment. This is because our adjusted image is now sitting beneath the layer. Next to the layer, a black screen appears (see Screenshot 2). If a 'Reveal All' mask is used, the screen is white. We then click the brush icon (see Screenshot 2). We can alter the size of our brush by using the square bracket keys – '[' makes our brush size smaller, and ']' larger. Ensure for a 'Hide All' mask your brush is white – Screenshot 3 indicates how to identify this. For 'Reveal All' masks the brush needs to be black.

We now brush in the areas we want to see the increased 'Brightness/Contrast' adjustment. As we move over these areas, we can see the change we saved down to the layer below appearing through without affecting the rest of the image (see Screenshot 3). The black screen next to our layer also shows the areas we are amending.

The last stage is to apply a 'Gaussian Blur' ('Filter › Blur › Gaussian Blur'), which enables us to blend our brush strokes. This means our changes are subtly integrated into our image. It is an essential follow-on step after using either mask. The 'Radius' slider allows us to control our blur, so that changes appear natural. Each time we make a change that we are happy with, we start a new layer that carries these changes forward by pressing 'Shift, Alt, Ctrl, N and E' simultaneously. We repeat these steps with other functions in Photoshop's 'Adjustments' menu. Our final image (see opposite, top, left) shows vibrance, selective colour and 'Hue/Saturation' amendments applied with our 'Hide All' mask.

Your best photos submitted to the magazine this month

ASTROPHOTOGRAPHY GALLERY

More **ONLINE**
A gallery containing these and more of your images

PHOTO OF THE MONTH

◁ Mineral Moon

Prabhakaran (Prabhu), Mleiha, UAE, 15 February 2020

Prabhu says: "The Moon is often seen in shades of grey, but by adjusting the colours and saturation in post-processing you can bring out the true colours of its mineral composition. The blue and orange shades indicate volcanic lava flows; the dark blues indicate that those areas are richer in titanium-bearing minerals. Pink indicates the iron-poor, aluminium-rich minerals that make up the lunar highlands. Orange and purple indicate regions that are relatively poor in titanium and iron."

Equipment: ZWO ASI 290MC colour camera, GSO 16-inch Dobsonian reflector, EQ platform **Exposure:** Mosaic of 19 x 2' videos (2,368 frames per video at 3.9ms shutter speed) **Software**: AutoStakkert!, Image Composite Editor, Photoshop

Prabhu's top tips: "You need patience, good equipment and excellent atmospheric seeing conditions to get a high-resolution Moon image. It's best to capture it when it's high in the sky and less affected by the atmosphere. Use a big reflector with an aperture of 8 inches or above, with a tracking mount to capture the disc panel by panel, which can later be stitched together. A high-speed planetary colour camera can capture more frames and with software like AutoStakkert! you can stack the good frames and discard the rest."

△ Comet C/2020 F3 NEOWISE

Dave Connolly, County Laois, Ireland, 11 July 2020

Dave says: "This was taken at a bog lake in Portarlington. As I approached I was delighted to see the comet had cleared the treeline and was casting a reflection on the water. This was going to be a tricky shot, with an unexpected but welcome display of NLCs along the northeast horizon. Behind me I noted the Moon in its waning glory, plus Jupiter and Saturn. It was an unforgettable night."

Equipment: Fuji X-T2 camera, 50-150mm lens **Exposure:** ISO 800 f/2.8, 12" **Software:** Lightroom Classic

◁ The Cat's Eye Nebula

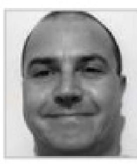
Douglas Struble, Taylor, Michigan, USA, 8 June 2020

Douglas says: "I layered in three sets of Ha and OIII data at various exposures and added in RGB stars."

Equipment: ZWO ASI 1600MM Pro, Explore Scientific ED APO 165mm FPL-53, Astro-Physics GTO-Mach 1 **Exposure:** 30h total **Software:** SGP, PixInsight, Photoshop

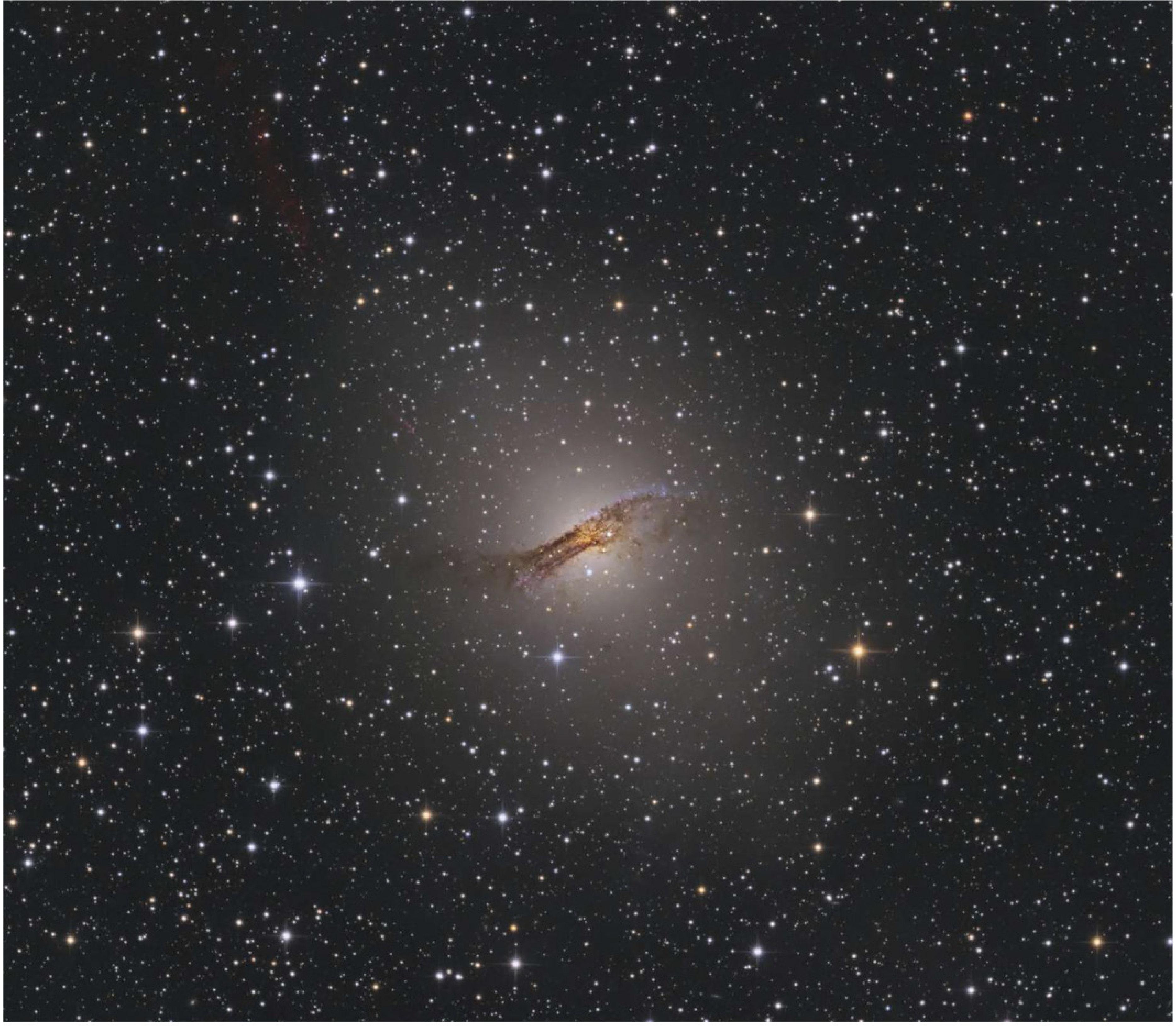
◁ The Lagoon and Trifid Nebulae

Davide Mancini, Perth, Australia, 25 June 2020



Davide says: "I've always wanted to get M8 and M20 together in the same frame, and when I got my new wide-field rig I was able to do it. I wanted to keep the image as natural as possible, so I waited for the new Moon and shot a straight RGB without any filters. Acquiring the data was easy, but the challenge was in the post-processing, trying to get as much detail without saturating the stars."

Equipment: ZWO ASI 2600MC Pro camera, SharpStar 150mm f/2.8 Newtonian, Sky-Watcher HEQ5 mount **Exposure:** 96 x 300" **Software:** SGPro, PixInsight



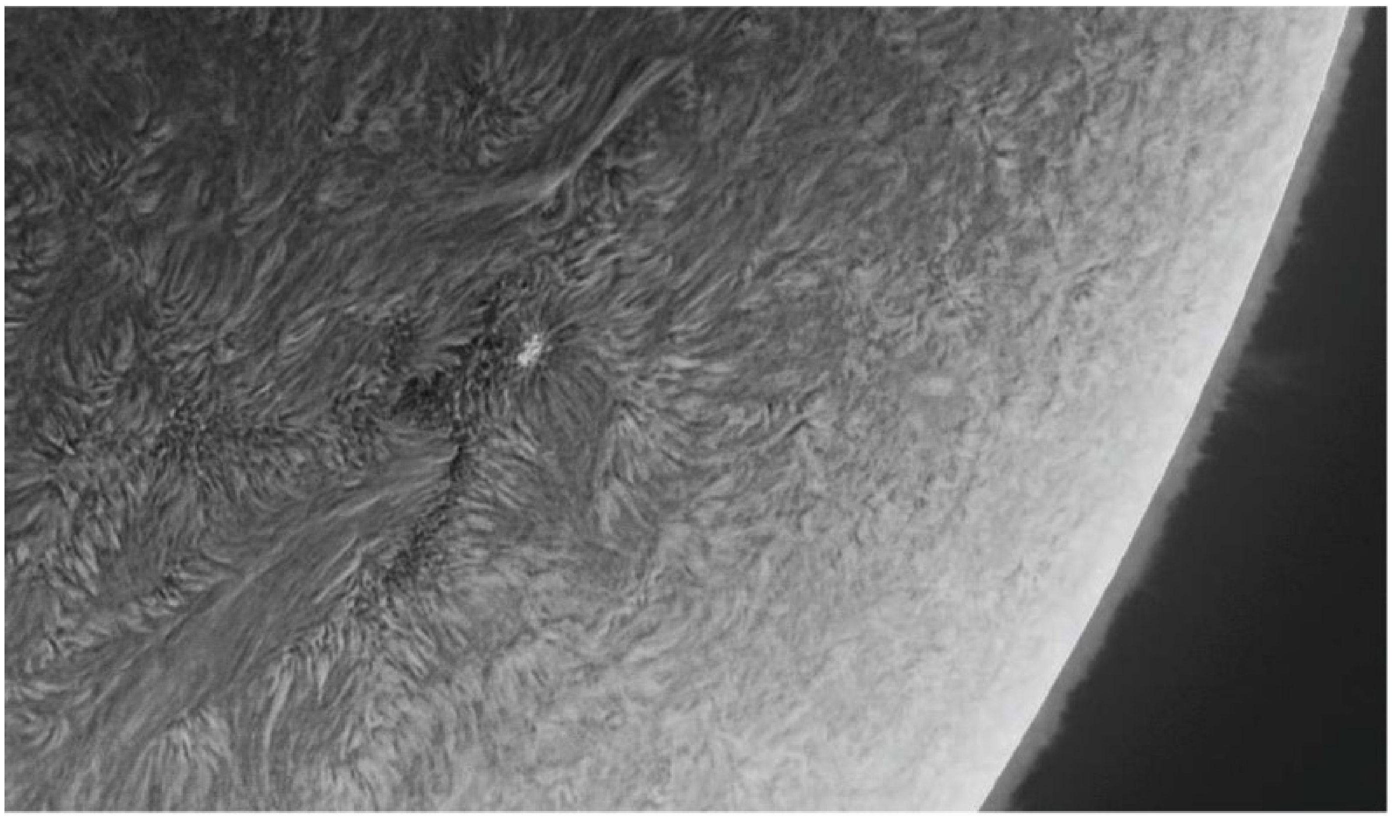
△ Centaurus A

Fabio Mirra, Jean-Christophe Philippe and Didier Rediger-Lizlov, remotely via El Sauce Observatory, Chile, 15 April 2020



Didier says: "We are a team of three friends, 'Los Calvos', and this image of Centaurus A was the first light of our remote setup at El Sauce Observatory in the Río Hurtado Valley, Chile. One of our challenges was to be able to render the hydrogen jets of this beautiful galaxy."

Equipment: Moravian Instruments G4-16000 camera, PlaneWave Instruments CDK 12.5-inch astrograph, Astro-Physics 1100 GTO mount **Exposure:** LRGB 18h 30', Ha 28h **Software:** PixInsight, Photoshop



△ Sun spot

Jean-Paul Desgrees, Chartres, France, 13 June 2020

Jean-Paul says: "The Sun has fascinated me since 1973 when I was secretary of the solar commission of the Astronomical Society of France. It's in a period of low activity in its 11-year cycle at the moment, so when I captured this spot I thought I'd share it with you."

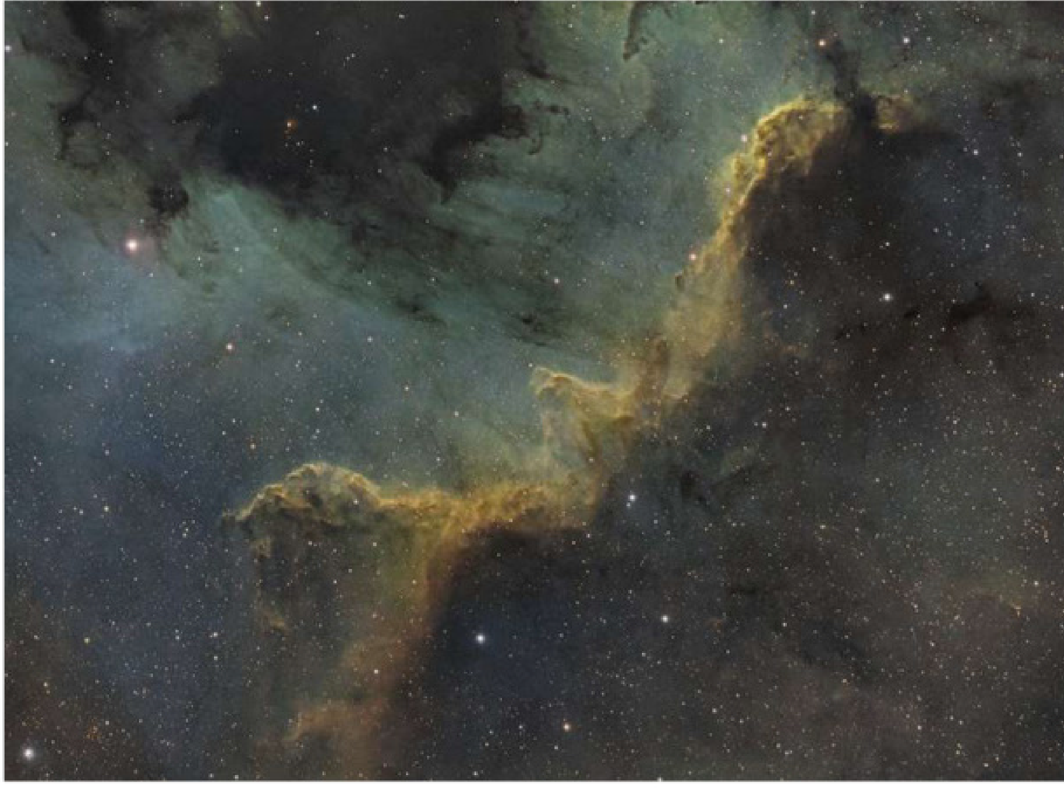
Equipment: ZWO ASI 178MM mono camera, TS-Optics Photoline 130mm triplet apo refractor, Daystar Quark H-alpha Eyepiece, Daystar Energy Rejection Filter, UV-IR cut filter, Sky-Watcher EQ8 mount **Exposure:** 30" video **Software:** FireCapture, AstroSurface, RegiStax, Photoshop

▽ Comet C/2017 passing M106

Vivek Chari, Texas, USA, 24–25 June 2020

Vivek says: "This was my first time capturing a comet and I only had a window of three nights. The first night was frustrated by clouds, while the second was plagued by equipment failures. Luckily, on the third night the clouds cleared and the stars aligned – it was well worth the effort."

Equipment: Nikon D5300, Stellarvue SV80 apo refractor, Sky-Watcher EQ6R Pro mount **Exposure:** 8.7 hr, ISO 200 **Software:** NINA, PixInsight



△ The Cygnus Wall

Jason Burns, Kansas, USA, 22–24 June 2020

Jason says: "Last year I shot this with a one-shot colour camera and I knew I could do better with narrowband filters. I found OIII a challenge to complete as the data always seems a little more noisy, while post-processing was tedious as I wanted a true 'Hubble Palette' (SII, Ha, OIII) and didn't want green overpowering the image. Fortunately, the skies were pristine and the data was clean, so I didn't have to lose any sub exposures."

Equipment: QHY163M camera, Sky-Watcher 100ED Pro apo refractor, pier-mounted Celestron AVX mount head **Exposure:** 15 x 600" SII, HA, and OIII **Software:** APT, DeepSkyStacker, PixInsight

The Andromeda Galaxy ▷

Nishant Revur, Washington, USA, 19 June 2020

Nishant says: "Andromeda has captivated me since I was a child. When I started astrophotography a little under a year ago, this target always eluded me as it was obscured by buildings. I finally got the chance to drive out of the city and capture this magnificent galaxy. Shooting this from Bortle 3 skies was well worth the wait."

Equipment: ZWO ASI 294MC Pro colour camera, William Optics RedCat 51 apo refractor, Celestron Advanced VX mount **Exposure:** 35 x 300" **Software:** Astro Pixel Processor, PixInsight

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78
Three pairs of 7x50 binoculars are on test this month

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HOW WE RATE

Each product we review is rated for performance in five categories. Here's what the ratings mean:

★★★★★ Outstanding ★★★★★ Very good
★★★★★ Good ★★★★★ Average ★★★★★ Poor/avoid

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3 OF THE BEST

7x50 binoculars from £100–£200

Begin your stargazing binocular adventure with wide views of the night sky

WORDS: PAUL MONEY

Nikon Action EX 7x50 CF

Price £169 • **Field of view** 6.4° • **Weight** 1kg • **Extras** Multi-click adjustable eyecups, front and back lens covers, wide strap, rubber armouring, nitrogen-filled waterproof optics, tripod mounting, carry case • **Supplier** Nikon UK • **www.**nikon.co.uk

At just 1kg, the Nikon Action EX 7x50 CF binoculars are light and can be used for long periods of observing without overly tiring your arms. They come with a soft padded case, but surprisingly this doesn't have its own strap. The binoculars feature multi-click turn-and-slide eyecups that work well with and without spectacles, and a good range of adjustment for interpupillary distance (the distance between the pupils of your eyes) at 56–72mm.

Like many popular binoculars, these are centre focusing (alluded to in their name by the 'CF'): you can make dioptre adjustments to the right-hand eyepiece and then use the centre focuser to bring everything into sharp focus. This is smooth in action, as is the right-hand eyepiece which has a thumbwheel adjustment. The lenses are multi-coated for better contrast and, when tested, they gave good colour rendition of stars such as the Garnet star and Antares, while the interior blackout was excellent.

So what is the view like? Interestingly, the actual field of view was the smallest of the three pairs of binoculars on review at 6.4°, but stars were crisp almost out to the field edges; we could just fit the 'box' section of Lyra, bordered by Beta (β), Gamma (γ), Zeta (ζ) and Delta (δ) Lyrae, in the view. Our tour of the summer Milky Way began by sweeping across Cassiopeia, up to Cygnus and down through Scutum to end with a glimpse in the light skies of M8, the Lagoon Nebula.

Generally 7x50 binoculars are best-suited to large-scale objects, so viewing the star clouds along the way was enjoyable, while there was enough light grasp and resolution to spot many of our favourite targets. The Double Cluster, low in the northeast, was nicely framed, while on the other side of the sky we picked out the Coma Star Cluster, M111, while the Sagittarius Star Cloud, M24, filled the view nicely.

Naturally, with such a wide field of view the Moon appeared small, but it looked stunning, with no hint of colour fringing. We could also just make out that Jupiter had four small companions – its Galilean moons – and amazingly we were able to catch them, with two placed on either side of the gas giant. Saturn also displayed a hint of being oval, which added to our enjoyment and satisfaction.

VERDICT

Overall, a great quality pair of binoculars with good colour rendition for double stars

FOR Lightest of the three, sharp optics, great internal blackout and well-fitting caps

AGAINST Smallest field of view at 6.4°, and the carry case doesn't have its own strap

OVERALL SCORE ★★★★½

ALL PICTURES: @THESHED/PHOTOSTUDIO

Opticron Marine-3 7x50

Price £189 • **Field of view** 7.2° • **Weight** 1.1kg • **Extras** Rubber eyecups, front and back lens covers, wide strap, rubber armouring, nitrogen-filled waterproof optics, tripod mounting, carry case • **Supplier** Opticron UK • **Tel** 01582 726522 • **www.**opticron.co.uk

Opticron's Marine-3 7x50 binoculars are rubber-armoured, waterproof and come in a soft case with its own strap. The binoculars have a nice rugged feel and weigh 1.1kg, which is not too heavy for prolonged use. The eyepieces rubber cups are quite stiff, but once folded back they allow spectacle wearers to enjoy the views. Like most binoculars of this size, the Marine-3's accommodate a wide range of interpupillary distance, anything between 56–75mm, which is suitable for most people.

Although the front lens caps are each attached to the barrels with a long rubber strap, we found these were long enough to occasionally swing round and catch you in the face. The good news is they are attached via the tripod bush adaptor and so they can be taken off when needed. The eyepieces can be focused separately, which appeals to many night-sky aficionados because it makes the focus harder to accidentally change.

As with all our binoculars, the Marine-3s can be attached to a tripod for extra stability. We found this helped when we were trying to split the double star Albireo, which we could just about do but only with a tripod. The actual field of view is 7.2°, which meant our view of the 'box' section of Lyra was easily fitted in with a bit of room to spare. We also found we could fit almost all of Delphinus in the view, apart from one star. The Milky Way star fields were just as good and we enjoyed touring around from Cassiopeia to Sagittarius, picking out the Sagittarius Star Cloud, M24, the Omega Nebula, M17, the Wild Duck Cluster, M11 and even the tiny Ring Nebula, M57, as a dot in Lyra.

The Andromeda Galaxy was poorly placed low in the northeast, but we could see that under darker skies it would be an extensive object. The colour contrast was good too, with the orange and red Garnet star appearing gorgeous under a moderately good but light summer night. The crescent Moon had a very slight colour fringe when placed nearer the edge of the view, but otherwise it was good, although Jupiter's four moons were not as easily separated, probably due to the slightly wider field of view. ▸

VERDICT

A nice pair of binoculars for general and astronomical use, with a good carry case

FOR Independent focusing of the eyepieces and good colour contrast

AGAINST Front objective caps can fall back into your face at high viewing angles

OVERALL SCORE ★★★★☆

Helios Stellar-II 7x50

Price £169 • **Field of view** 7.2° • **Weight** 1.1kg • **Extras** Foldable rubber eyecups, front and back lens covers, padded strap, rubber armouring, nitrogen-filled waterproof optics, tripod adaptor, carry case • **Supplier** Optical Vision Ltd • **Tel** 01359 244200 • **www.**opticalvision.co.uk

With a green and black rubber-armoured outer skin, the Helios Stellar-II binoculars have a stylish look and feel with good grip. The front lens caps fit snugly and are directly attached to the underside of the objective barrels so they cannot drop onto your face and can be quickly put back on for protection. The eyecups are rubber and can be folded down to enable spectacle wearers to see the full field of view, although they are a little stiff. The actual field of view is 7.2°, so quite wide with a little distortion towards the edges, but nothing too distracting. We could fit the 'box' part of Lyra in comfortably and these binoculars are ideal for scanning along the Milky Way's star fields.

Both eyepieces can be focused independently with a smooth action, and the interpupillary distance (the distance between the pupils of your eyes) can be adjusted between 56–74mm, a range which will cover most users. All the optical surfaces are multi-coated for better contrast; we found that Arcturus and the Garnet star appeared as crisp orange stars, but we still needed to mount the binoculars on a tripod to split Albireo.

On the tour of our test objects in the night sky, we noted the Andromeda Galaxy covered a good proportion of the view with a hint of its galactic disc, but under darker skies we suspect the view would have been better. The Double Cluster sparkled despite being small, but both component clusters were easily seen. The star fields in Cygnus were well seen, and we caught the star cluster M39 as a small triangular shape. Indeed, the Cygnus Rift, an area of the Milky Way obscured by dark dust clouds, was nicely traced and continued down into Scutum where we had a good view of the Scutum Star Cloud. Nebulae may be small, but we saw the Dumbbell Nebula as a small smudge, along with the Omega Nebula, lower down in the south at the time of viewing.

Although the crescent Moon was small in the evening twilight it was a delight, as we could see Mare Crisium, although we did notice a little colour fringing when it was placed towards the edge of the field of view. With the binoculars on a tripod, we could make out four of Jupiter's moons and a definite oval shape to Saturn, which suggested a hint of its ringed nature.

ALL PICTURES: @THESHED/PHOTOSTUDIO

VERDICT

A good all-round pair for a wide range of uses, featuring a nice grip and good front lens caps that fit really well

FOR **A firm feel and easy to hold thanks to rubberised grip**
AGAINST **Slight colour fringing on the Moon towards the edges**

OVERALL SCORE ★★★★☆

Lacerta MGEN-3 stand-alone autoguider

A compact, portable and easy-to-use tracking solution for astrophotographers

WORDS: CHARLOTTE DANIELS

VITAL STATS

- **Price** £609
- **Weight** 1.1kg
- **Controller** Handheld control box
- **Camera** 1.2MP, 1280 x 960, CMOS AR0130CS monochrome guide camera
- **Extras** 4GB micro SD card, camera adaptors, cables
- **Software** Virtual Interface and Sky Emulator PC applications
- **Supplier** 365 Astronomy
- **Tel** 020 3384 5187
- **www.**365 astronomy.com

Guiding can be a daunting step in astrophotography and progressing to a laptop-controlled setup can introduce frustrations with new software and hardware. It's worthwhile though, as guiding can lead to longer exposure times, which becomes increasingly important as you embark on deep-sky photography. So the Lacerta MGEN-3's simpler alternative to 'full-on' guiding, one where a laptop and additional software isn't needed, is exciting.

Opening the MGEN-3's box we were surprised by the lack of components. There's the autoguider control box (a lightweight 40g), a 1.2MP guide camera, two USB leads and an ST4 guiding cable. Adaptors for different setups are also provided with the camera, providing up to 26mm backfocus for different configurations. No paper instructions are provided but there's an easy-to-follow manual on the website.

Setup simplicity

The MGEN-3 builds on its predecessor, the MGEN-2, by offering improvements including multi-star guiding to reduce atmospheric distortions, and a 'one-push' autoguiding function. It also offers DSLR/CCD exposure control in place of an intervalometer, along with built-in 'drift (polar) alignment' and 'dithering' functions. 'Drift alignment' helps those unable to view Polaris from their imaging location, while 'dithering' creates minute movements of the camera between exposures, to reduce noise – unwanted artefacts – in an image.

After fixing the camera to our guidescope, we only had to link it to the control box, and the control box to our mount and power via the supplied cables. The 'Esc' button on the control box led to the main menu and, after adding the focal length of our guider, we navigated to 'Imaging', which shows a live image to help focus. The 'one-push' start button function immediately started picking up guide stars, meaning we were ready to begin.

We found the camera sensitive even in summer twilight – it picked up 70 guide stars for the North America Nebula with our 50mm guiderscope. We put ▸

Standing out

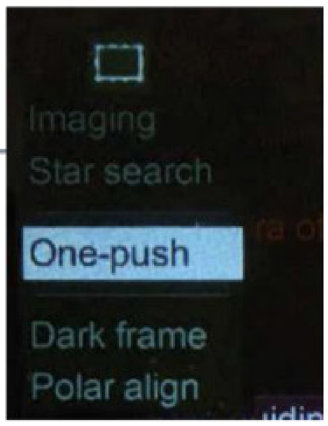
The 'stand-alone' element of the MGEN-3 autoguider is impressive. We found the equipment completely plug-and-play and the control box comes with a 'live view' function in place of a laptop screen. Once attached to the guidescope, we were up and running within minutes.

When you go the conventional, laptop-driven route, common problems can include incorrect drivers, lack of USB ports, cable management and disconnection issues. With the MGEN-3 we encountered none of these. There is the option, though, to connect via a laptop (and Lacerta provides apps to do this), which means you can get used to laptop-controlled setups before moving up to the standalone integrated guiding equipment and software. The flexibility means we could switch between the two options, depending on the location we were imaging from, and this makes the MGEN-3 even more adaptable. Overall, we couldn't think of anything else that the Lacerta MGEN-3 needs to do when we compared it to specialist guiding software.

ALL PICTURES: @THESHED/PHOTOSTUDIO

LCD display

The crisp, colour LCD screen is easy to read and navigate. The four main menus comprise DSLR exposure control, 'one-push' guiding, functions and calibrations, and display customisation. The layout of the menus is similar to that of a DSLR, so it will feel familiar to many users.



Handheld control box

The controller fits nicely in the palm of the hand and comes with an LCD display and simple push-button design. Despite its small size, it packs a punch, with a 32-bit CPU and 64MB RAM. Control buttons are backlit with red lighting, making it easy to change settings in darkness.

Artificial Intelligence (AI) programming

The AI programming can capture up to 100 stars in the camera's field of view, allowing for a greater guiding accuracy of 1/50 pixels. Combined with the camera's sensitivity, we were able to detect enough stars to maximise exposure times for our DSLR, even in lighter summer skies.

Ports

All ports are located at the base of the control box and include a DSLR out, AUX, USB (for connection to the guide camera) and an ST4 guide port. There is also USB-in for connection to a power source. As the MGEN-3 draws about 240mA, it can be powered via a portable powerpack.

KIT TO ADD
1. ZWO MiniScope 30mm f/4 mini guide scope
2. ZWO 60mm finder and guide scope
3. LACERTA EOS-1 or EOS-2 exposure cable

▸ the MGEN-3 through its paces with a 10-minute exposure, noticing round stars were kept consistently round. This was great for something we had plugged in with almost no adjustments and polar alignned completely manually. Guiding graphs were clear, and we noted that the arrow buttons on the control box flashed to signify the directional adjustments the MGEN-3 was making, which was a nice touch. Each time we used the kit, it took about five minutes for the graphs to settle into a consistently smooth guiding pattern.

Adaptable for experts

The MGEN-3's 'dithering' function is also simple to use. It's adjustable, but we opted for the default setting of 10 pixels and obtained significantly reduced noise in our final DSLR image. We shot the North America Nebula with 'dithering' enabled and the Elephant's Trunk Nebula with it disabled, and noted significant difference. Browsing through the various menu options, we saw that declination can be switched off, which allows for use with a number of portable tracking mounts – another good feature for beginners. In terms of add-ons, we particularly liked the dark frame routine, which applies dark frames to remove hot pixels from the guide camera image and reduces the risk of interrupted guiding.

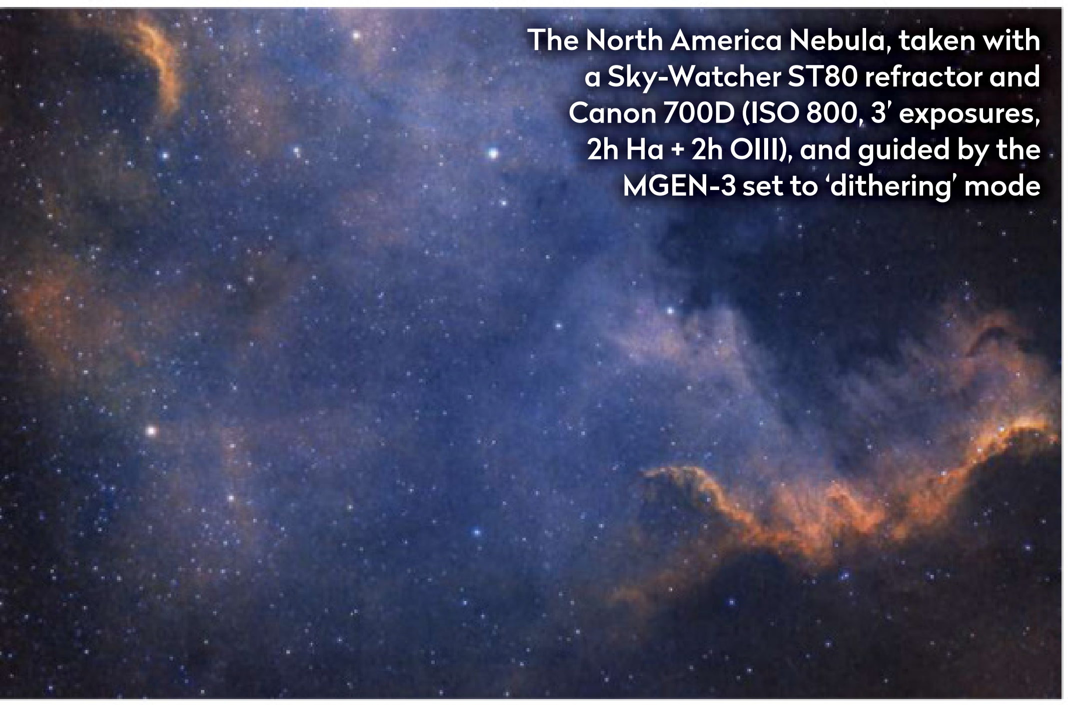
Essentially, the MGEN-3 comes with everything needed to guide quickly, accurately and reliably, without a laptop and mains power – we didn't feel we were missing anything from our regular guiding routine. While the interface is basic, there are several calibration settings provided to adapt for more advanced imagers, meaning this kit also has plenty to offer more experienced astrophotographers. Lacerta is looking to add additional features via firmware updates and these will be free for a year after purchasing. Under investigation is plate solving, which we would be keen to see. The Lacerta MGEN-3 autoguider is engineered to be as easy as possible to use, and if future functions adopt the same straightforward approach, it will continue to hold its own among heavyweight guiding equipment.

Guide camera

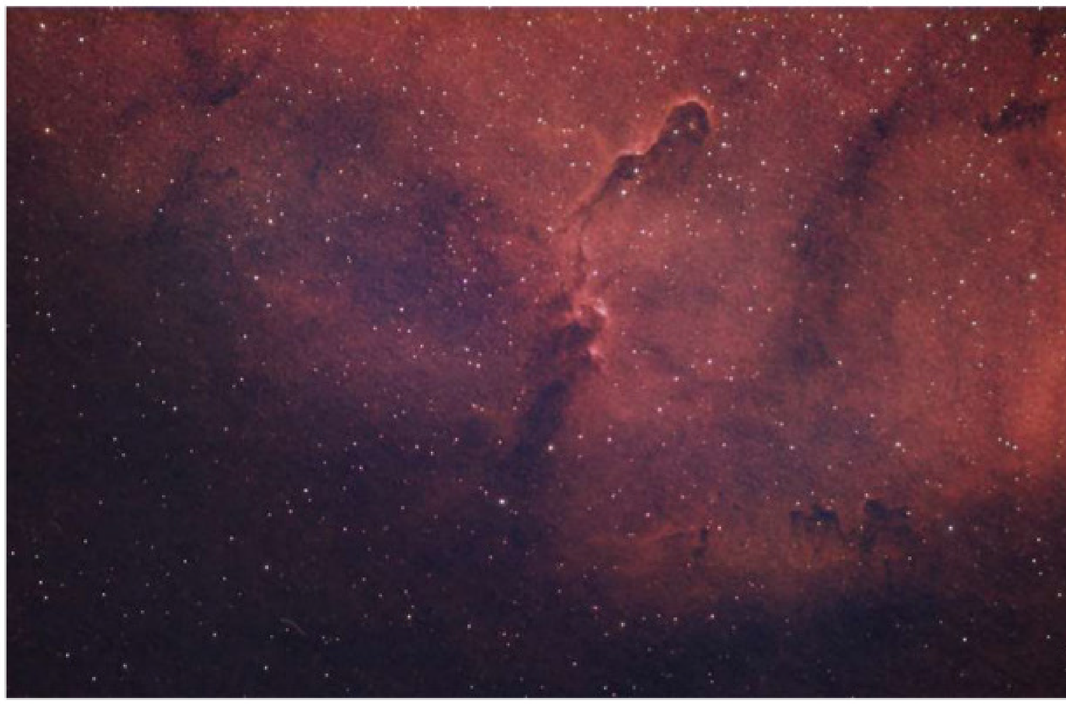
The compact, sensitive guide camera is designed to fit any guidescope. Its sensor, the monochrome AR0130CS, provides 3.75µm pixels across an area of 4.8mm x 3.6mm. Its aluminium casing allows passive cooling to reduce noise, while the MGEN-3's zoom function enables more precise focusing of the guide camera via the guidescope.

VERDICT

Build & design	★★★★½
Connectivity	★★★★☆
Ease of use	★★★★★
Features	★★★★½
Guiding accuracy	★★★★½
OVERALL	★★★★½



The North America Nebula, taken with a Sky-Watcher ST80 refractor and Canon 700D (ISO 800, 3' exposures, 2h Ha + 2h OIII), and guided by the MGEN-3 set to 'dithering' mode



▾ The Elephant Trunk Nebula, as imaged by a Sky-Watcher ED80 and modified Canon 700D (ISO 800, 3' exposures, 2h Ha + 2h RGB) and guided by the MGEN-3 set to 'no dithering'

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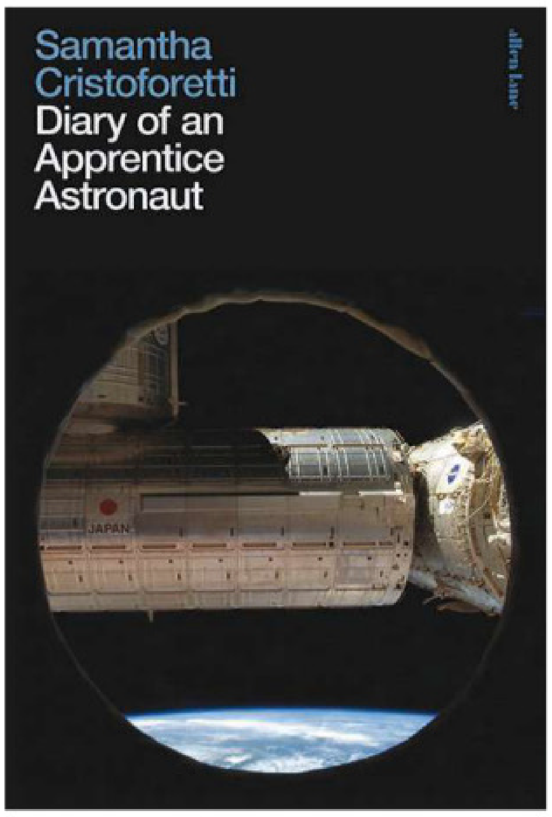
BOOKS



Diary of an Apprentice Astronaut

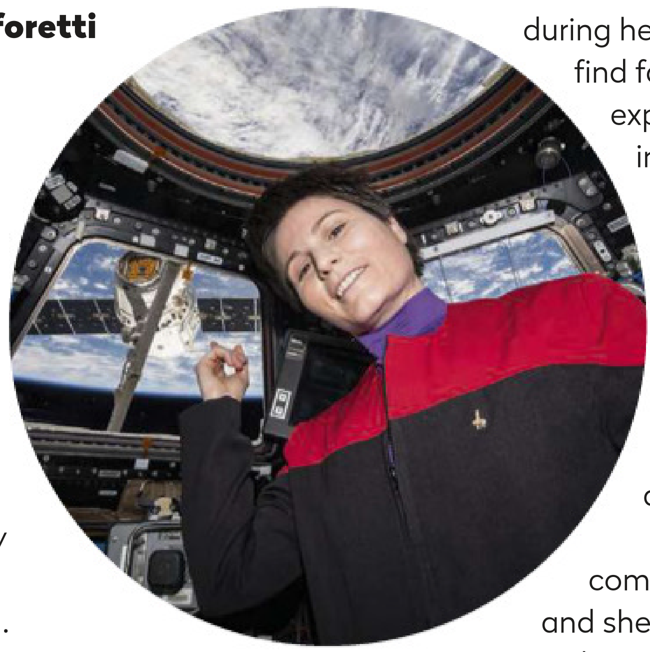
Samantha Cristoforetti
Allen Lane
£25 ● HB

At the sight of the International Space Station (ISS) passing over us, you may wonder what it's like to be up there, orbiting Earth every 93 minutes. You may even wave at the astronauts on board. After nearly 20 years since the first crew inhabited the ISS, the smallest details of living in space and the rigorous training the astronauts undertake continue to fascinate.

Diary of an Apprentice Astronaut opens with Italian astronaut Samantha Cristoforetti hurtling back through Earth's atmosphere in a Soyuz descent module, a dramatic account that wouldn't go amiss in the opening scenes of a film.

We follow Cristoforetti through her application process, astronaut training and preparation for ISS Expedition 42/43, her ISS tenure and, finally, the return to Earth. A large part of the diary focuses on her training, and by the time launch day arrives it almost feels like you too have experienced the rigorous program alongside her as you share her excitement at boarding the Soyuz rocket.

Cristoforetti has a poetic and often philosophical narrative style that is woven through much of her diary, giving it a refreshingly distinctive quality, but it is the depth of detail that makes this book unique. There are some parts where the details are crammed to the brim but, as this is the closest most readers will come to experiencing astronaut training, many will eagerly indulge in every crumb. Fans of the Space Race will particularly enjoy the rich and nostalgic descriptions of Star City, while those who followed Cristoforetti's social media posts during her ISS residence will find familiar events expanded on with fresh insights. The diary structure and her generosity in sharing her thoughts and feelings balances out what would otherwise make for a rather dense read.



▲ Samantha Cristoforetti, pictured in 2015 on board the ISS

NASA/ESA

Cristoforetti's committment is striking, and she fully owns her ambition to become an astronaut and reach the ISS, as well as the mistakes made along the way. Becoming an astronaut is an extraordinary feat, but her story is a very human one that still manages to be relatable and hard to not draw inspiration from. ★★★★★

***Nisha Beerjeraz-Hoyle** is a space and astronomy writer*

Interview with the author
Samantha Cristoforetti

Does being on the ISS affect your perception of Earth?

Being in space blurs out the details and gives you an appreciation of the global scale. Thinking about global problems such as climate change doesn't require abstract thinking: the planet is beneath you, with its atmosphere, ice caps, oceans and weather patterns. We're constantly embracing the entire Earth, one orbit every 90 minutes. The idea that it's one big system, that everything is interrelated becomes visually obvious, it's an immediate perception like that of your own body.

What research did you undertake during your mission?

I worked directly on roughly 50–60 experiments, both in the physical sciences domain – such as combustion, fluid mechanics, material science – and in the life sciences. The experiments that astronauts are most involved with are the human physiology ones, for which we serve as both the operators and the object of the observation. I did research on sleep, on the cardiovascular system, on the immune response, on lung function, on balance and motor control and on bone health.

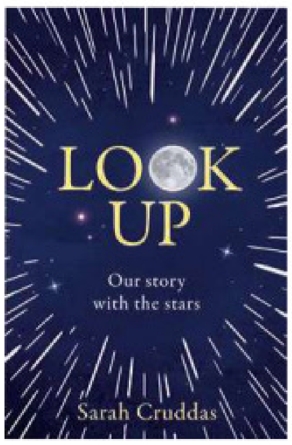
What was most thrilling, the journey to the ISS or the journey home?

Both were unique experiences, physically and emotionally intense, but different in terms of meaning. The launch was the beginning of the adventure, it held the promise of those 6–7 months of extraterrestrial life. The journey home was an amazing ride, falling back to Earth in a ball of fire, but there was also an undertone of melancholy about leaving the ISS and wrapping up that part of my life.

***Samantha Cristoforetti** is a European Space Agency astronaut and engineer*

Look Up: Our Story with the Stars

Sarah Cruddas
Harper Collins
£16.99 ● HB



How many people have been to space? What is the future of space travel? And why is it important to continue to travel and explore the heavens? These and other questions are explored in Sarah Cruddas's comprehensive history (and future) of space travel.

Cruddas is a space journalist, giving her unprecedented access to the people involved in historical and current space travel. Her book puts human stories at the centre. We hear not only about each mission and the astronauts involved, we also learn of those back on Earth, in mission control and of the families left behind.

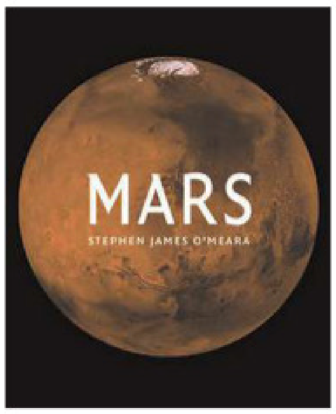
The book begins with a summary of astronomy and flight before the Space Race. There then follows a detailed account of that race to get the first person on the Moon. From there, we learn about the unanticipated consequences of space exploration, the 'unexpected space age', such as the first photo of Earth from space that inspired the environmental movement and the technological advances that shape our everyday lives. Finally, Cruddas looks to today, as private companies try to make space tourism a reality.

At its best, this book is so full of optimism. The story of Apollo and Challenger missions fills the reader with a sense of pride in the unity and possibility of the human spirit. It is hard not to feel a tinge of sadness at the narrower, more conventional ambitions of today. That said, Cruddas does her best to offer hope. ★★★★★

***Emily Winterburn** is a science historian and author of* The Stargazer's Guide

Mars

Stephen James O'Meara
Reaktion
£25 ● HB



Our love affair with Mars is deeply rooted in history, dating back to the fifth and sixth millennia BC when the Sumerians believed that Mars was the god of plague and war. We have been fascinated with its physical characteristics since Galileo observed the planet through a telescope in 1609 and Christiaan Huygens drew the first map of its surface in 1659. The opening chapters of *Mars* span three centuries and provide an interesting insight into these human relationships and discoveries. O'Meara then explores the Space Race and travelling beyond the Moon, taking us on a journey of disappointment and joy as the two superpowers compete to reach the Red Planet. From Marsnik 1 to ExoMars, to how the newly developing internet first made modern Mars mission data accessible to a curious public, this is a fascinating topic.

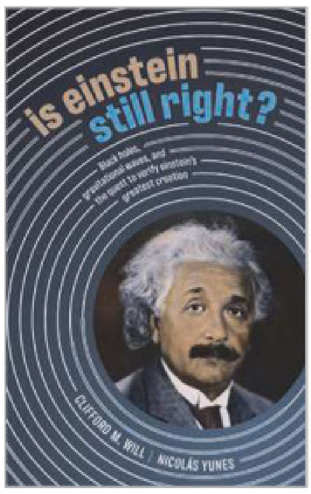
For readers investigating Mars for the first time, the impressive collection of glossy photographs taken by rovers and orbiters will astonish, and may even make you question if what you are seeing is real. If you've ever wondered about life on Mars or what Martian blueberries look like, O'Meara will provide you with the answers. Looking to our future, he explains how humans will journey to the Red Planet, the risks involved and even the ethical challenges we face. Concluding the book with useful appendices, including a timetable of future oppositions for the next 15 years (the next of which will occur this October), *Mars* will appeal to historians, planetary geologists and anyone with an interest in space exploration. ★★★★★

***Katrin Raynor-Evans** is an amateur astronomer and librarian for Cardiff Astronomical Society*

Is Einstein Still Right?

PACKED WITH FACTS

Clifford M Will & Nicolás Yunes
Oxford University Press
£16.99 ● HB



After reading this great book, you'll never forget the three naked physicists who came up with the idea for Gravity Probe B, the NASA satellite that confirmed Einstein's prediction of frame dragging – the slight warping of space by massive, rotating bodies like the Earth. It's these kind of funny anecdotes that make *Is Einstein Still Right*? such a great read.

Relativity guru Clifford Martin Will and his younger colleague Nicolás Yunes conclude that yes, Einstein's theory of general relativity is still right, but no, we can't be sure there won't be a better and more fundamental description of space, time and gravity around the corner. After all, general relativity doesn't match with quantum physics, so scientists haven't found the final answer yet.

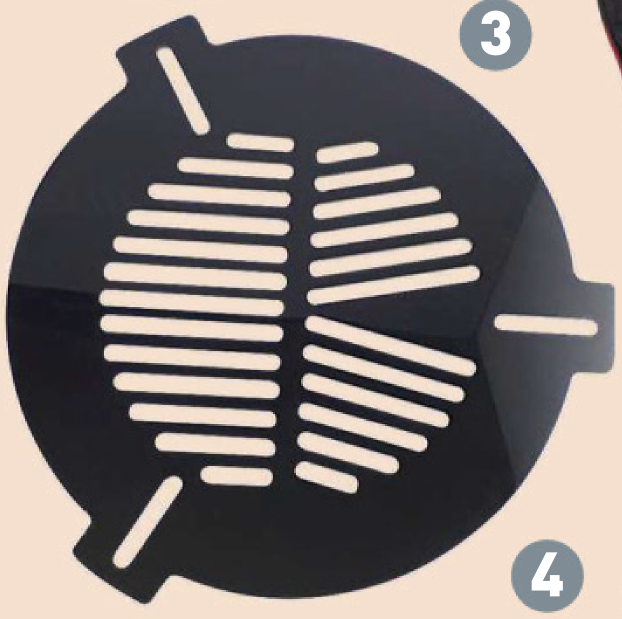
Starting with the detection of gravitational redshift and the bending of starlight by the gravity of the Sun, Will and Yunes provide an entertaining overview of the many tests that general relativity has been put to over the past 100 years or so, introducing pulsars and black holes along the way. In fact, the book contains a lot more interesting stuff – and nice personal anecdotes – than the title suggests.

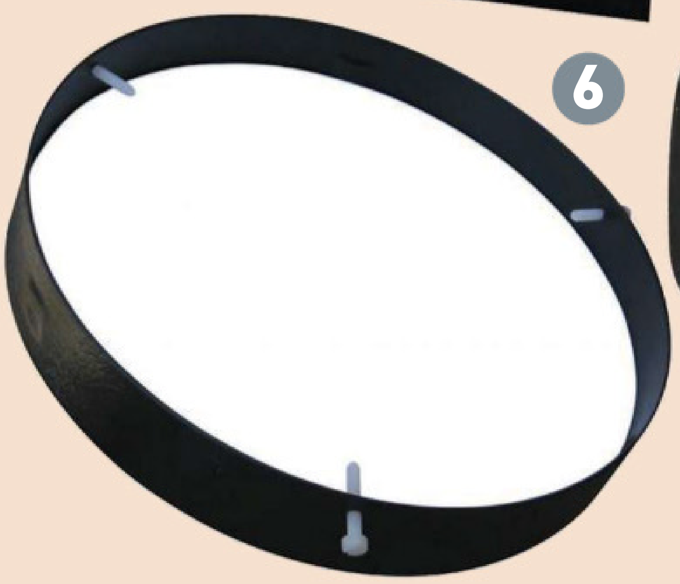
The last third is devoted to the search for and detection of gravitational waves over the past few years, and how future gravitational wave detectors (like the European Einstein Telescope and the space-based LISA interferometer) may change our view of the cosmos again. Here, too, the authors strike the perfect balance between depth and accessibility, using helpful metaphors wherever it is necessary. ★★★★★

***Govert Schilling** is an astronomy writer and the author of* Ripples in Spacetime

Ezzy Pearson rounds up the latest astronomical accessories

GEAR





1 Orion filter wheel package

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4 Landfall 3D moon images

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These 3D maps are created using the natural topography of the Moon to shape beautiful lunar images. Each is made to order, so you can choose your favourite lunar landmark to transform into a work of art.

5 Cosmos mini bamboo trays

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Add some retro space chic to your home with these four bamboo mini trays, which commemorate some of the greatest achievements of the early Space Race.

6 Geoptik flat field panel

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Calibrating using a flat field panel helps to solve the problem of unevenly illuminated deep-sky images. It fits onto scopes with an external diameter of 250mm to 308mm, with plastic screws to hold it in place.

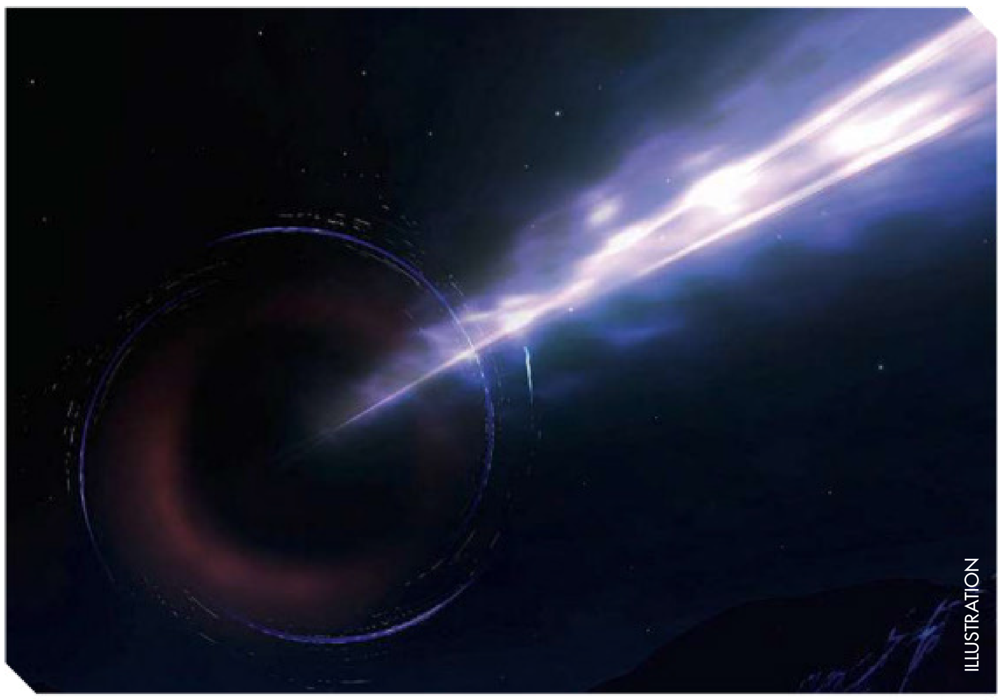
Shaoni Bhattacharya interviews Dr Elizabeth Stanway

Q&A WITH AN EXTRAGALACTIC STAR MODELLER

How do gamma-ray bursts occur in massive stars when they die? The answer could tell us more about how galaxies – and even life – evolve

What is a gamma-ray burst (GRB)?

When a massive star exhausts all of its fuel, it collapses under its own weight and dies in a supernova. When the star is very, very massive and is spinning rapidly at the same time as collapsing, it forms a black hole at its core and sends out jets of energy. A gamma-ray burst occurs when a very massive star collapses like this and we are looking along the line of the jet. We've got this beam of radiation pointing directly at us. It is tens or hundreds of times brighter than a normal supernova. GRBs can outshine entire galaxies.



▲ **Massive attack: a gamma-ray burst is far brighter than a normal supernova**

What are the main questions about how GRBs are formed?

The big question has been how you get a star that is that big and is still spinning really fast when it dies. The work I have been doing with my colleagues Ashley Chrimes and Dr JJ Eldridge has been to model this as a form of binary star interaction. It's saying the reason these massive stars are still spinning so fast when they collapse is because the companion star is stopping them from slowing down – it's spinning them up over time.

What did you do in your recent study in the *Monthly Notices of the Royal Astronomical Society*?

We have a set of stellar evolution models, which include the idea that stars could be transferring material from one star in a binary to a companion. A normal star will blow out winds and material off its surface over time, reducing its rotation. But if that material is preferentially going to a neighbour, and that is exerting a tide on the star, then it will get that star spinning faster again. We've calculated the effects of tides in these binary systems – it's the same effect the Moon has on the Earth and its oceans.

We were also looking specifically at binary stars. Given what we know about the prevalence of binaries and how stars are formed in the history of the Universe, does this set of models confirm observations?

It was consistent; our model could explain the data.

What was the key result?

We have a quarter of a million individual stellar evolution models, and for each one we can determine what's going to happen at the end: maybe only about 20,000 of them will explode. We looked to see whether the tidal effects in binaries were more or less likely to make these stars explode as GRBs.

The key thing is that until now, the previous models we had that keep these stars spinning only worked when we had metal-poor stars.

Our model, with the tidal effect, allows this spinning to happen in stars with higher levels of metals. It explains some of the observations that have suggested that these events are happening in galaxies quite rich in metals.

Dr Elizabeth Stanway is an associate professor working on stellar populations in galaxies at the University of Warwick, UK

What are the wider implications of your study?

A very small fraction of stars become GRBs, only stars more than about 20 to 25 times bigger than our Sun do this. Though extremely rare, when a GRB goes off it irradiates a very large volume – so they affect nearby stars and they can certainly affect any potential life in neighbouring star systems. Studying these systems may be important, as it helps us understand the areas in the Universe where life could potentially survive rather than being wiped out; you really don't want to be near a GRB.

Although we now live in a fairly quiet planetary system, on the edge of a fairly quiet Galaxy, in the past the Universe was forming stars at a much higher rate and these massive stars were impacting their surroundings in many ways. They were driving radiation and blowing gas and dust out of entire galaxies with the force of their radiation and supernovae.

So our research into the lives and deaths of these stars is important for our understanding of how galaxies have evolved over time.

MARK GARLICK/SCIENCE PHOTO LIBRARY/ISTOCK/GETTY IMAGES

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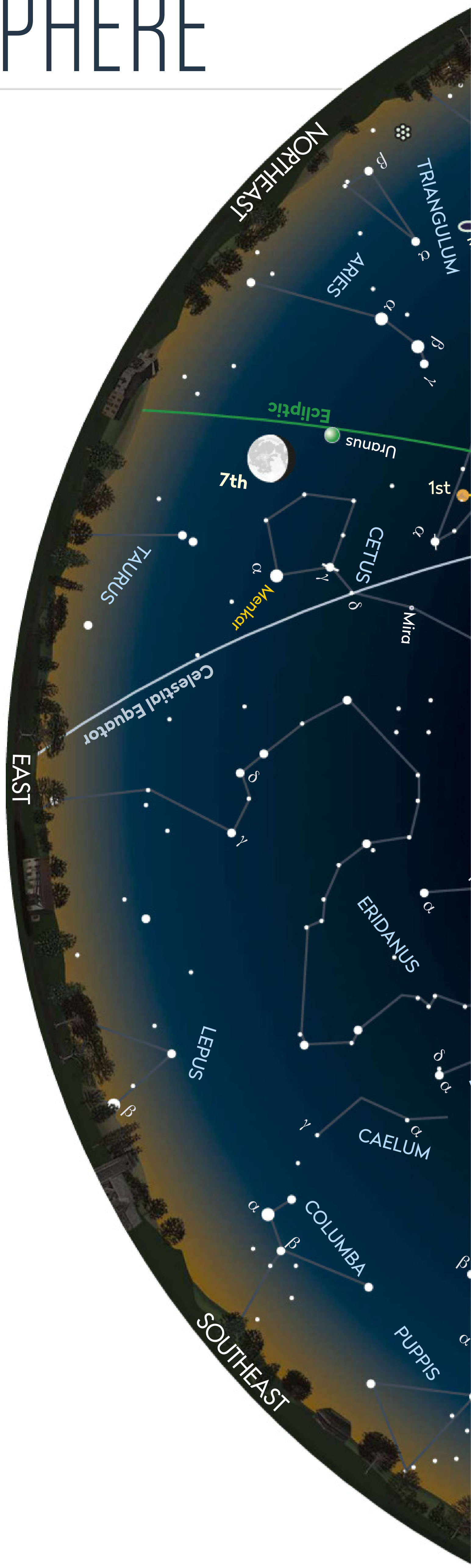
THE SOUTHERN HEMISPHERE

With Glenn Dawes

Try and follow Jupiter and Venus into daytime, and enjoy a dark-sky view of Capricornus



When to use this chart

1 Sep at 24:00 AEST (14:00 UT)
15 Sep at 23:00 AEST (13:00 UT)
31 Sep at 22:00 AEST (12:00 UT)

The chart accurately matches the sky on the dates and times shown for Sydney, Australia. The sky is different at other times as the stars crossing it set four minutes earlier each night.

SEPTEMBER HIGHLIGHTS

Jupiter can be seen during daylight, just look up. Well, not quite, as finding it is the trick. In the afternoon of the 25th the crescent Moon will be 1° from Jupiter, both fitting in the same binocular field. Once found, try it with the unaided eye. Although brighter, Venus presents the same challenge. The planet rises pre-dawn; try following it into daylight. On the 14th, the Moon makes a good marker. With either of these challenges, for comfort and safety, always stand in a building's shadow.

STARS AND CONSTELLATIONS

Capricornus, high in the northern evening sky, looks like a smile. Although invisible from suburbia this constellation of faint stars is obvious from the country. It's located in a mythologically 'fishy' region of the sky. Unlike nearby Pisces and Piscis Austrinus, it doesn't represent a normal fish but a Sea Goat. The story goes that the god Pan intended to jump into the Nile and turn into a fish, to evade a monster. He was too quick: his wet lower half turned into a fish's tail and the top into a goat.

THE PLANETS

Mercury commences a favourable evening return; for the later half of September it's well above the western horizon during twilight, spending much of this period within a few degrees of the bright star Spica. The early evening also sees Jupiter and Saturn up in the north, with Mars and Uranus rising and visible for the rest of the night. Neptune is at opposition and visible any time. The highlight in the morning is the beacon of Venus, low in the pre-dawn eastern sky.

DEEP-SKY OBJECTS

This month we visit the constellation of Piscis Austrinus. Eta (ε) Piscis Austrini (RA 22h 00.8', dec. –28° 27') is an impressive double star, with mag. +5.8 and +6.8 components, only 1.8" apart. A high power is needed to see these touching blue stars.

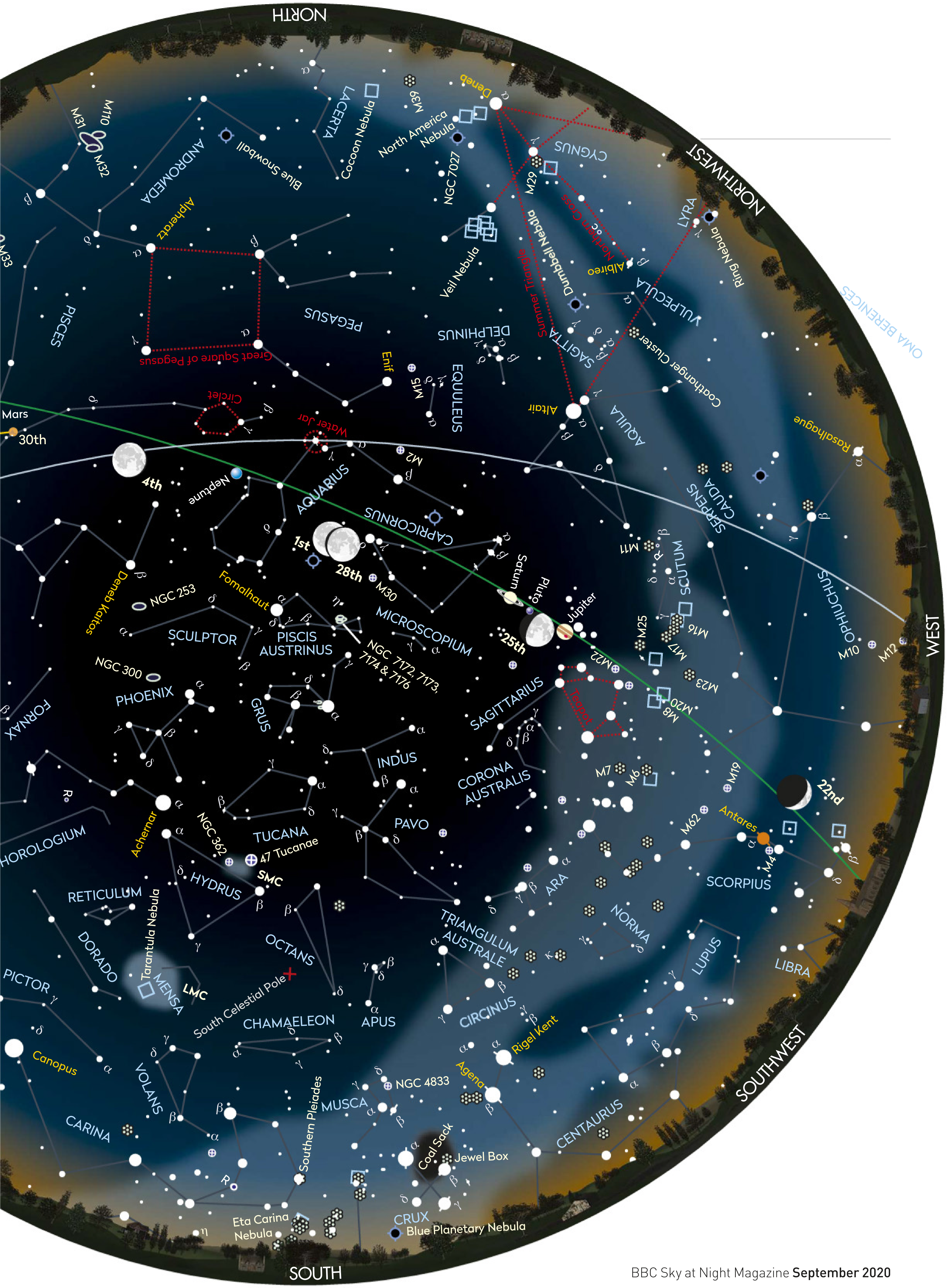
About 3° south of Eta lies a group of galaxies, four easily fitting in the same field. The most southern member is NGC 7176 (RA 22h 02.1m, dec. -31° 59'). This magnitude +11.1 elliptical is paired with another, NGC 7173, only 2' northwest. To the north (6' away) is the spiral NGC 7172, which is distinctively oval-shaped compared to the roundness of NGC 7173. Of the three, only NGC 7176 has a pronounced nucleus. To see the fourth galaxy you need to look closely at NGC 7176, which appears oval with the nucleus obviously offset eastward. Its western 'halo' is really the merging galaxy NGC 7174.

Chart key

- GALAXY
- OPEN CLUSTER
- GLOBULAR CLUSTER
- PLANETARY NEBULA
- DIFFUSE NEBULOSITY
- DOUBLE STAR
- VARIABLE STAR
- COMET TRACK
- ASTEROID TRACK
- METEOR RADIANT
- QUASAR
- PLANET

STAR BRIGHTNESS:
- MAG. 0 & BRIGHTER
- MAG. +1
- MAG. +2
- MAG. +3
- MAG. +4 & FAINTER

CHART: PETE LAWRENCE


NORTH
NORTHWEST
WEST
SOUTHWEST
SOUTH
LACERTA
Cocoon Nebula
M39
Deneb
North America Nebula
NGC 7027
CYGNUS
M29
Northern Cross
Albireo
Dumbbell Nebula
Summer Triangle
VULPECULA
LYRA
Ring Nebula
COMA BERENICES
Veil Nebula
DELPHINUS
SAGITTA
Coathanger Cluster
Altair
AQUILA
Rasalhague
M110
M31
M32
ANDROMEDA
Blue Snowball
Alpheratz
M33
PISCES
PEGASUS
Great Square of Pegasus
Enif
M15
EQUULEUS
Circlet
Mars
30th
Water Jar
M2
4th
Neptune
AQUARIUS
CAPRICORNUS
SERPENS CAUDA
1st
28th
M30
Saturn
Pluto
Jupiter
M11
SCUTUM
OPHIUCHUS
M10
M12
Deneb Kaitos
NGC 253
Fomalhaut
MICROSCOPIUM
25th
M25
M16
M17
SCULPTOR
PISCIS AUSTRINUS
NGC 7172, 7173, 7174 & 7176
M22
M23
NGC 300
PHOENIX
GRUS
SAGITTARIUS
Teapot
M20
M8
FORNAX
INDUS
CORONA AUSTRALIS
M7
M6
M19
22nd
HOROLOGIUM
Achernar
NGC 362
TUCANA
47 Tucanae
PAVO
M62
Antares
M4
HYDRUS
SMC
ARA
SCORPIUS
RETICULUM
Tarantula Nebula
DORADO
OCTANS
TRIANGULUM AUSTRALE
NORMA
LUPUS
LIBRA
PICTOR
MENSA
LMC
South Celestial Pole
CHAMAELEON
APUS
CIRCINUS
Rigel Kent
Canopus
VOLANS
Agena
NGC 4833
MUSCA
Southern Pleiades
CENTAURUS
CARINA
Coal Sack
Jewel Box
CRUX
Eta Carina Nebula
Blue Planetary Nebula